Supplemental Environmental Impact Statement for the Designation of Dredged Material Disposal Site(s) in Eastern Long Island Sound, Connecticut and New York

Physical Oceanography of Eastern Long Island Sound Region

Prepared for: **U.S. Environmental Protection Agency**

Sponsored by: **Connecticut Department of Transportation**

Prepared by: **University of Connecticut**

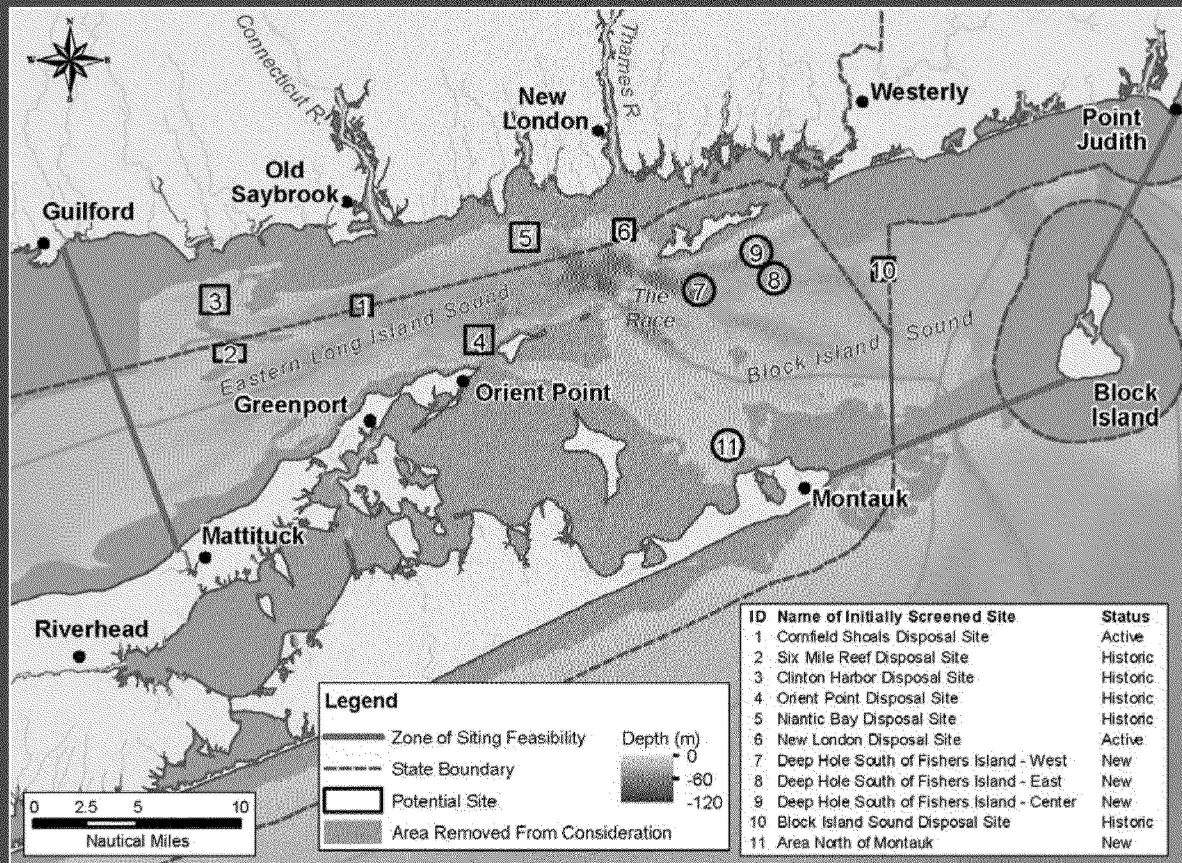
with support from: **Louis Berger**

Cooperating Agency Meeting 4 (Sept. 5, 2014)

Objective of PO Study

Support evaluation and selection of potential dredged material disposal sites within the Zone of Siting Feasibility (ZSF)

- Describe distribution of maximum bottom stress magnitudes expected in the ZSF including 'Superstorm Sandy' conditions **(a 100-year storm)**
- Characterize circulation in the ZSF to support assessment of potential off-site effects
- Acquire physical oceanography data to support future modeling of sediment transport at potential dredged material disposal sites



Zone of Siting Feasibility (ZSF). Initial screening identified (1) areas not suitable for locating dredged material disposal sites due to various constraints (gray zone), and (2) 11 sites for further investigation as potential disposal sites; these sites include two active and five historic disposal sites, and six 'new' sites not previously used for dredged material disposal. The background represents water depth.

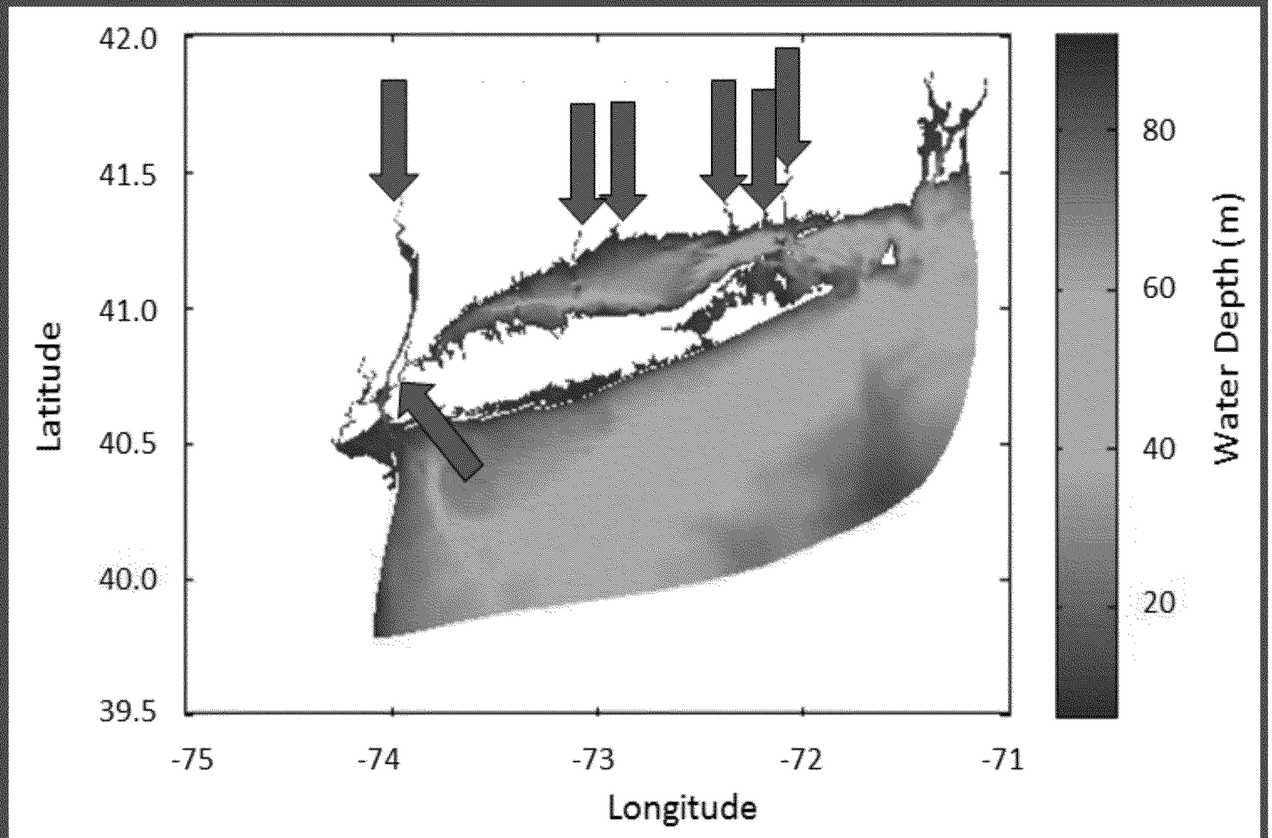
Outline

1. Model: *Configure and test*
2. Calibration: *Use available data*
3. Evaluation of Simulations
   - Field Program: *Collect data (currents and stress etc.) at a set of stations that are expected to exhibit a wide range of conditions*
   - Model Performance: *Evaluate predictions of model with new data*
4. Analysis
5. Summary

1. Model

FVCOM:

- Forced by Tides and NECOFS
- Observed River flow and wind
- Climatology for surface heat exchange
- Climatology for initial conditions



Bathymetry of the LIS model subdomain with the locations of freshwater sources (green arrows; from left to right: Hudson River, New York City wastewater treatment plants, Housatonic River, Quinnipiac River, Connecticut River, Niantic River, and Thames River).

1. Model *(cont.)*

An Unstructured Grid, Finite-Volume, Three-Dimensional, Primitive Equations Ocean Model: Application to Coastal Ocean and Estuaries

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Department of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

Conservation of Momentum: Reynolds Average Navier- Stokes Equation

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} - fv = -\frac{1}{\rho_o}\frac{\partial P}{\partial x} + \frac{\partial}{\partial z}\left(\boxed{K_m\frac{\partial u}{\partial z}}\right) + F_u,$$

At the seafloor

$$K_m\left(\frac{\partial u}{\partial z}, \frac{\partial v}{\partial z}\right) = \frac{1}{\rho_o}(\tau_{bx}, \tau_{by}),$$

where the stress is parameterized as

$$(\tau_{bx}, \tau_{by}) = \boxed{C_d}\sqrt{u^2 + v^2}(u, v)$$

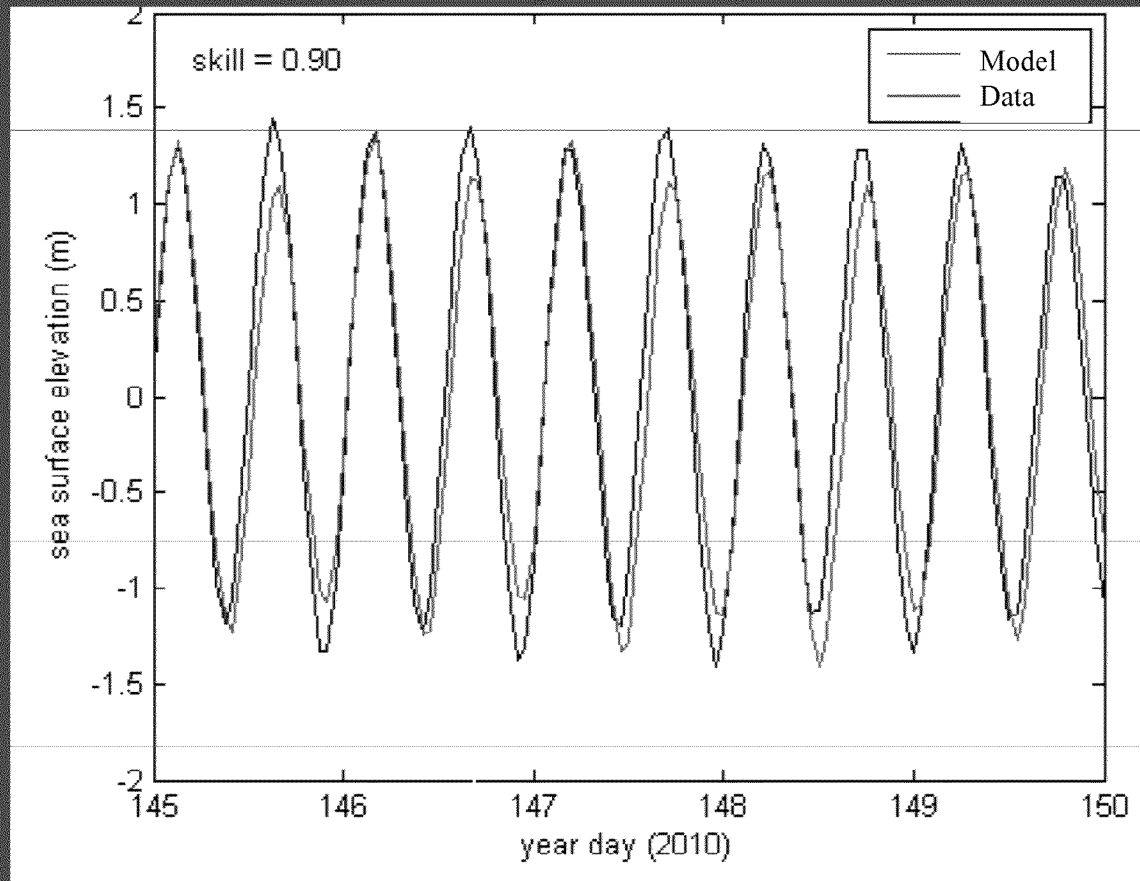
and the drag coefficient is written in terms of the roughness at the seafloor as

$$C_d = \max\left[\frac{k^2}{\ln\left(\frac{z_{ab}}{\boxed{z_o}}\right)^2}, 0.0025\right], \qquad (2.14)$$

where $k = 0.4$ is the von Kármán's constant and z_o is the bottom roughness parameter.

2. Calibration

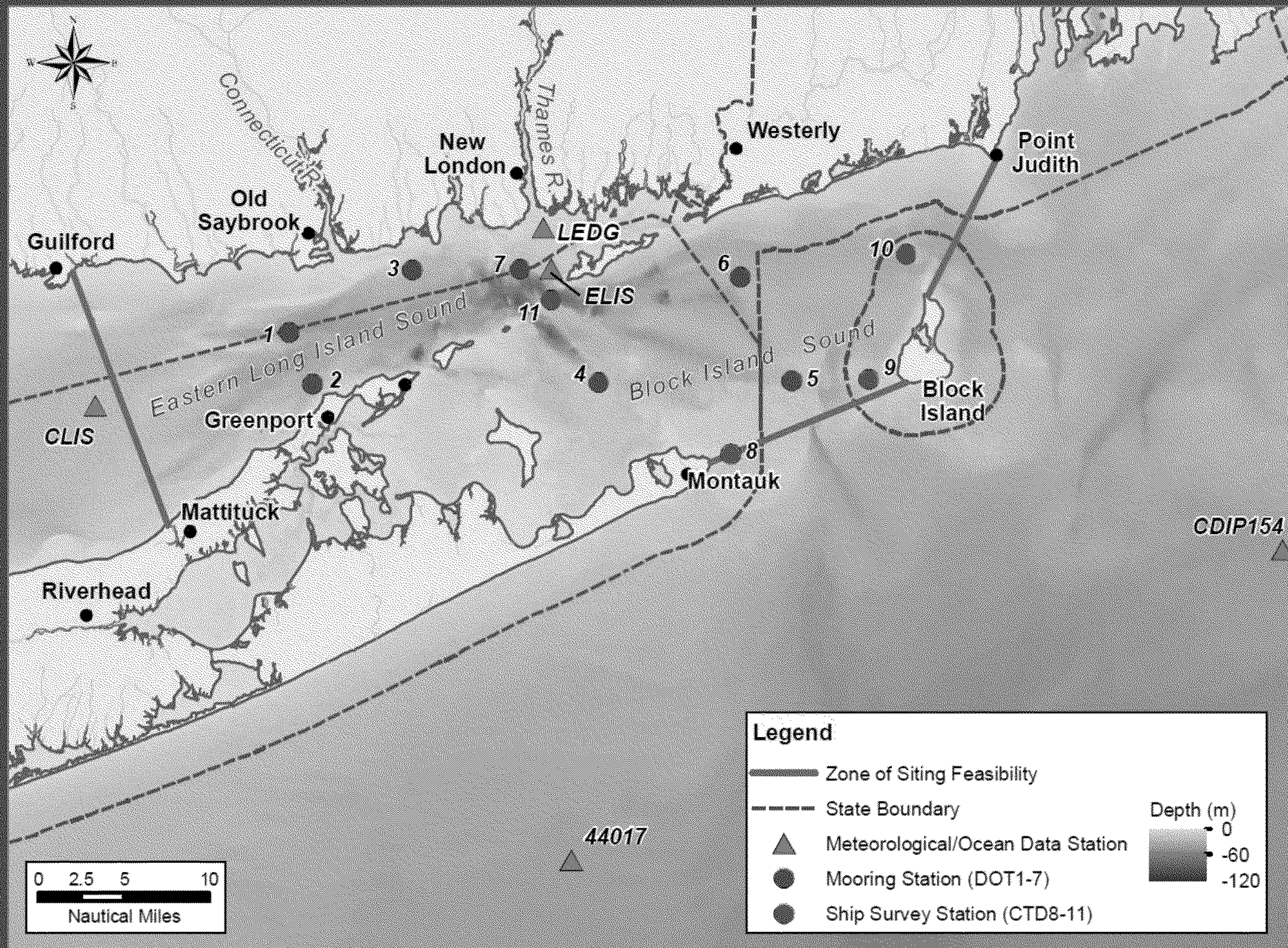
- Set z_0 =0.001 m to optimize the simulation of the sea level at Bridgeport for 2010
- Determine the Skill (variance in data explained/variance in data) to be 90%



Comparison of tidal heights at the NOAA Bridgeport tidal height gauge (BDR, blue) compared to those predicted by the FVCOM model (black) after iteratively calibrating the model using the 2010 NOAA data . Note that year day 1 is January 1, 2010.

3. Evaluation – Field Program

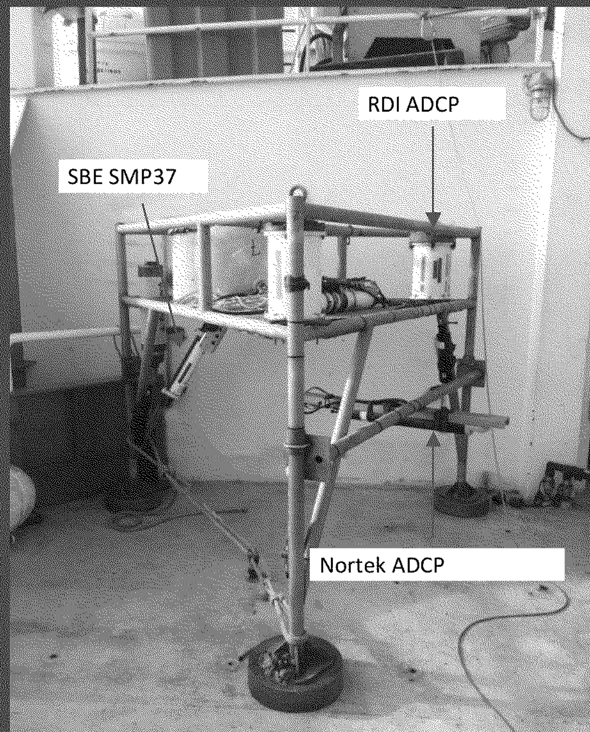
- Deploy instruments on 7 bottom tripods for 3 two-month observation campaigns to observe spring, fall and winter
- Conduct 6 cruises with water column measurements at the 7 tripod stations and 4 additional stations

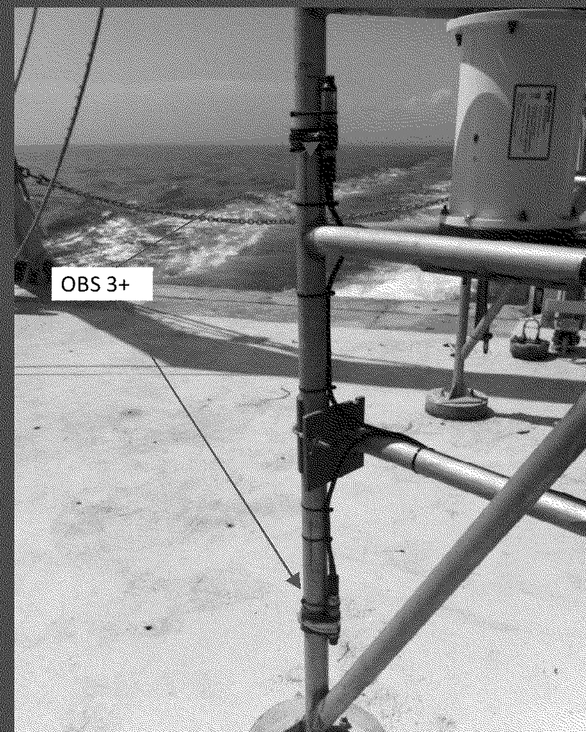


Survey stations in the ZSF, as well as meteorological/ocean stations. The background represents water depth.

3. Evaluation – Field Program *(cont.)*

- Upward looking RDI ADCP for water column currents and waves
- Downward looking Nortek ADCP for stress
- 2 optical backscatter (OBS3+) for suspended sediment concentration
- SeaBird CTD (SBE SMP37) for salinity and temperature

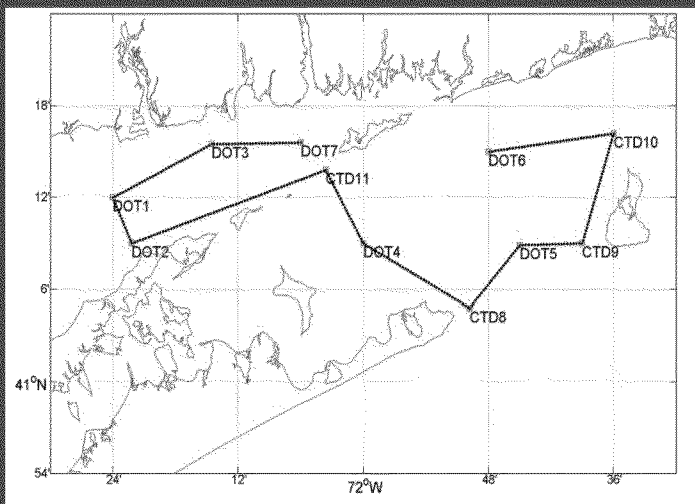




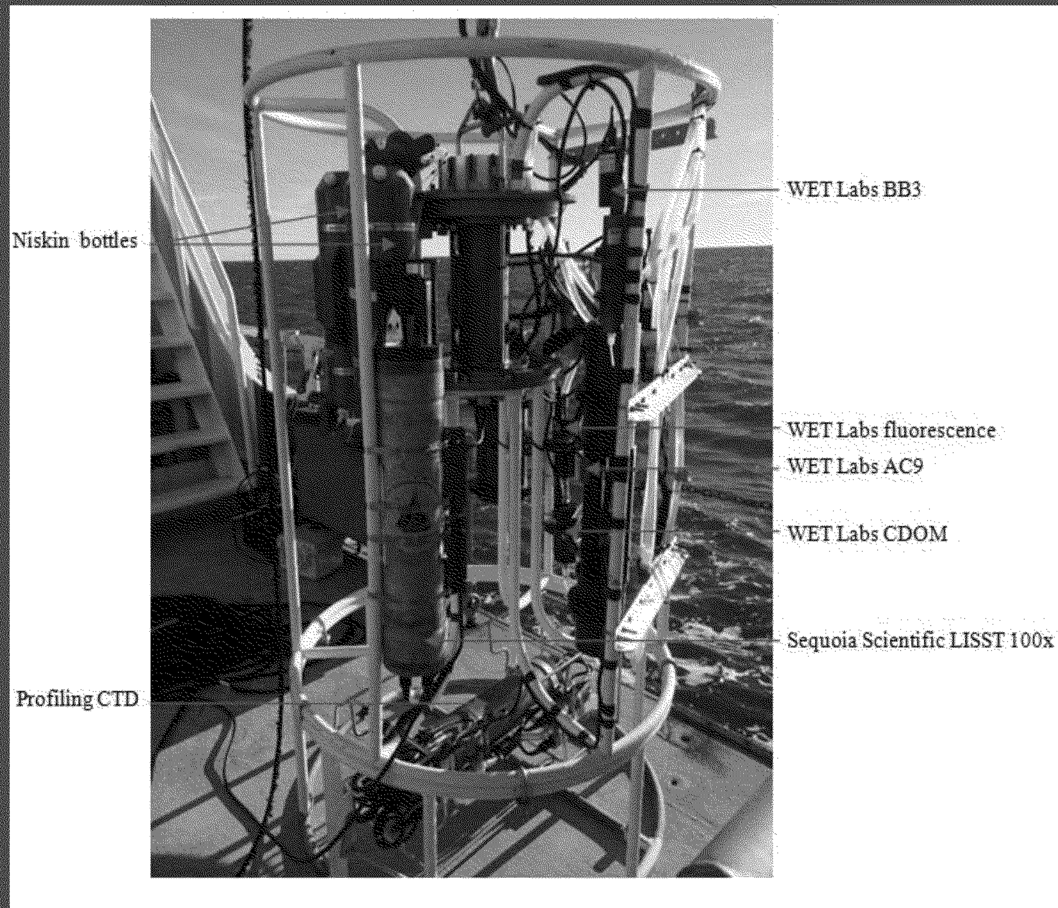
Left: Location of instruments in moored tripod frame
Right: Close-up of the OBS3+ mounts

3. Evaluation – Field Program *(cont.)*

- CTD for temperature and salinity
- Water sampler and optical instruments for future sediment transport modeling

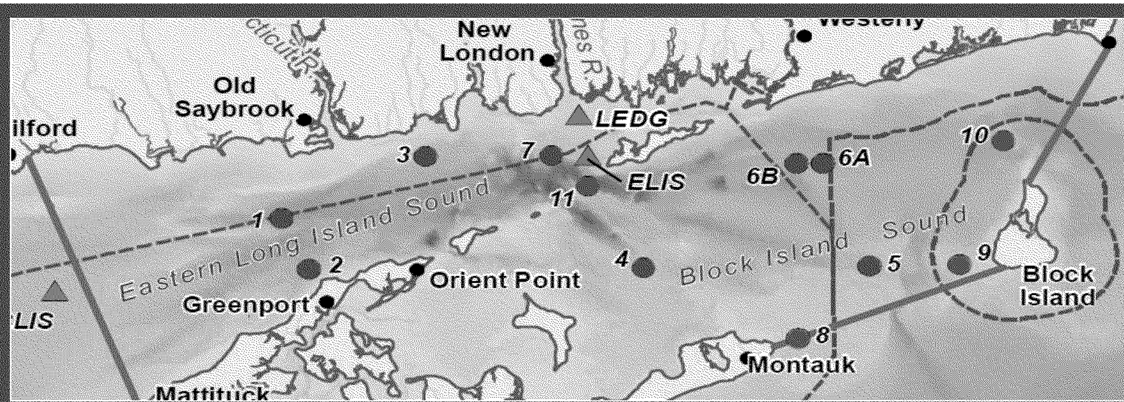


Example of a cruise track for ship surveys. The track varied for each cruise due to weather conditions and sea state.



Rosette sampler, equipped with a profiling CTD, Niskin bottles, and various optical sensors and particle analyzers.

Moored Stations – Data Recovery

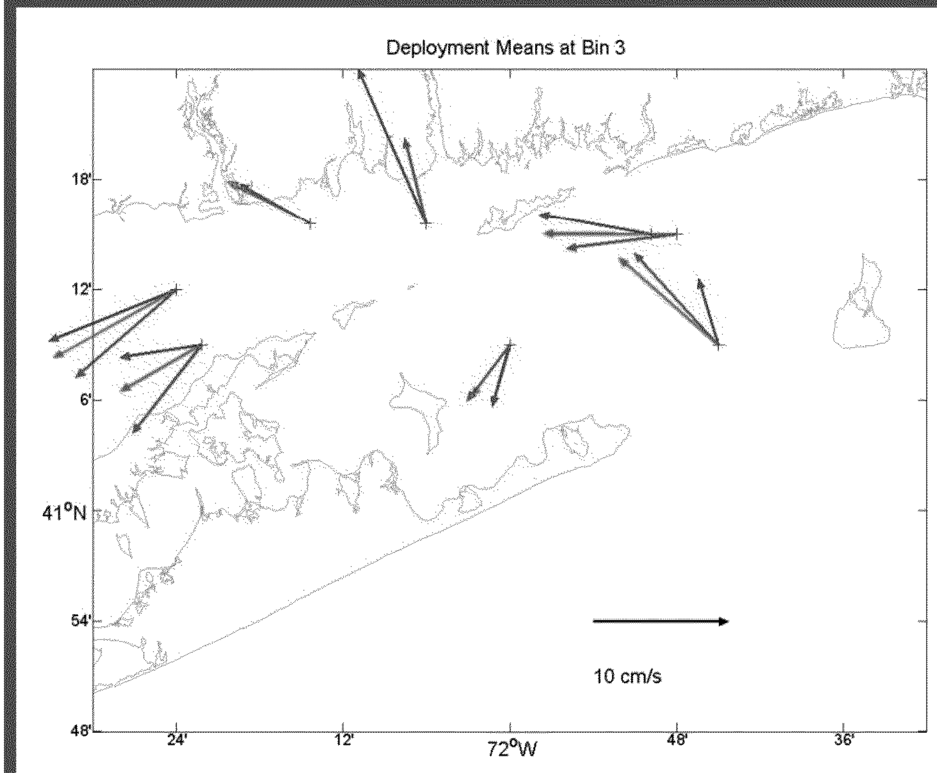


Parameters	Temperature and Salinity near the Seafloor				Currents and Suspended Sediment near the Seafloor				Waves and Currents in the Water Column			
Sensor	*CTD (SBE SMP37)*				*Nortek ADCP & OBS3+ sensor*				*RDI ADCP*			
Mooring Stn	Campaign			Total	Campaign			Total	Campaign			Total
	1	2	3		1	2	3		1	2	3	
	days				days				days			
DOT1	66	58	57	181	25	29	54	108	66	58	57	181
DOT2	66	58	57	181	25	27	54	106	66	58	57	181
DOT3	**6**	58	57	181	24	32	53	110	0	58	57	115
DOT4	**6**	58	57	181	27	34	56	117	66	58	57	181
DOT5	66	58	57	181	27	30	57	114	66	58	57	181
DOT6 A/B	**6**	58	43	167	25	16	44	86	28	16	43	87
DOT7	49	58	57	164	28	34	27	89	0	58	57	115
Max Days	*66*	*58*	*57*	*181*	*66*	*58*	*57*	*181*	*66*	*58*	*57*	*181*

(dark grey)	Full or near-full data (>90%)	(light grey)	About one quarter or more data (22.5 - 45%)
(light)	About half or more data (45 - 90%)	(dark)	No data

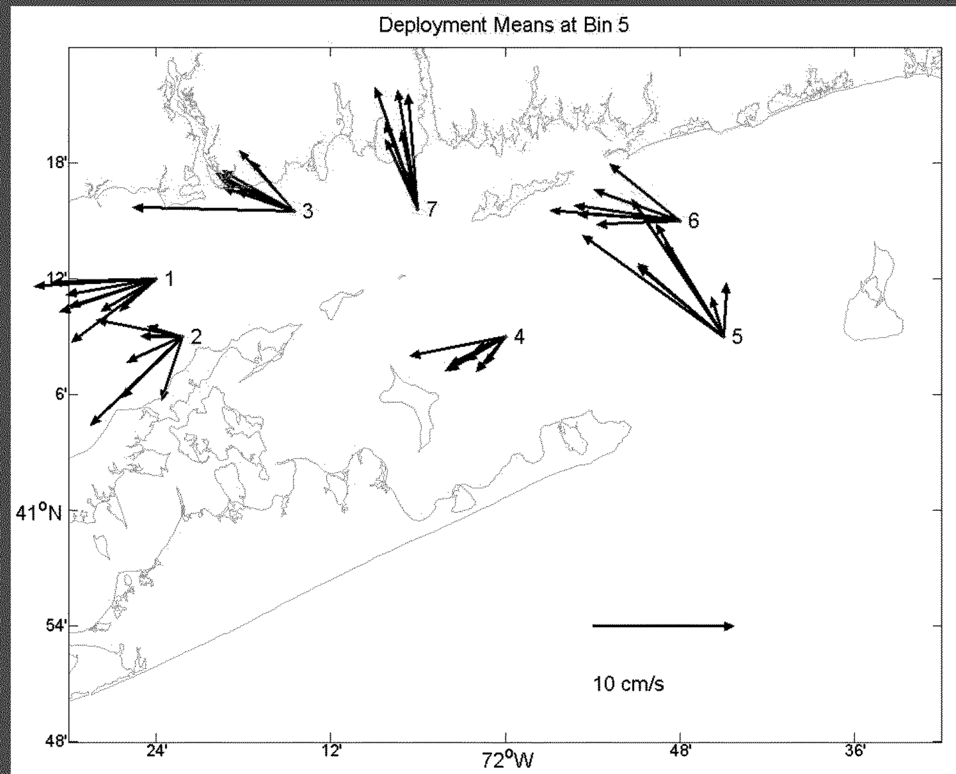
3. Evaluation – Field Program *(cont.)*

RDI ADCP means at ~3m from seafloor



Mean currents at Bin 3 of the RDI ADCP measurements during Campaigns 1 (green), 2 (red), and 3 (blue).

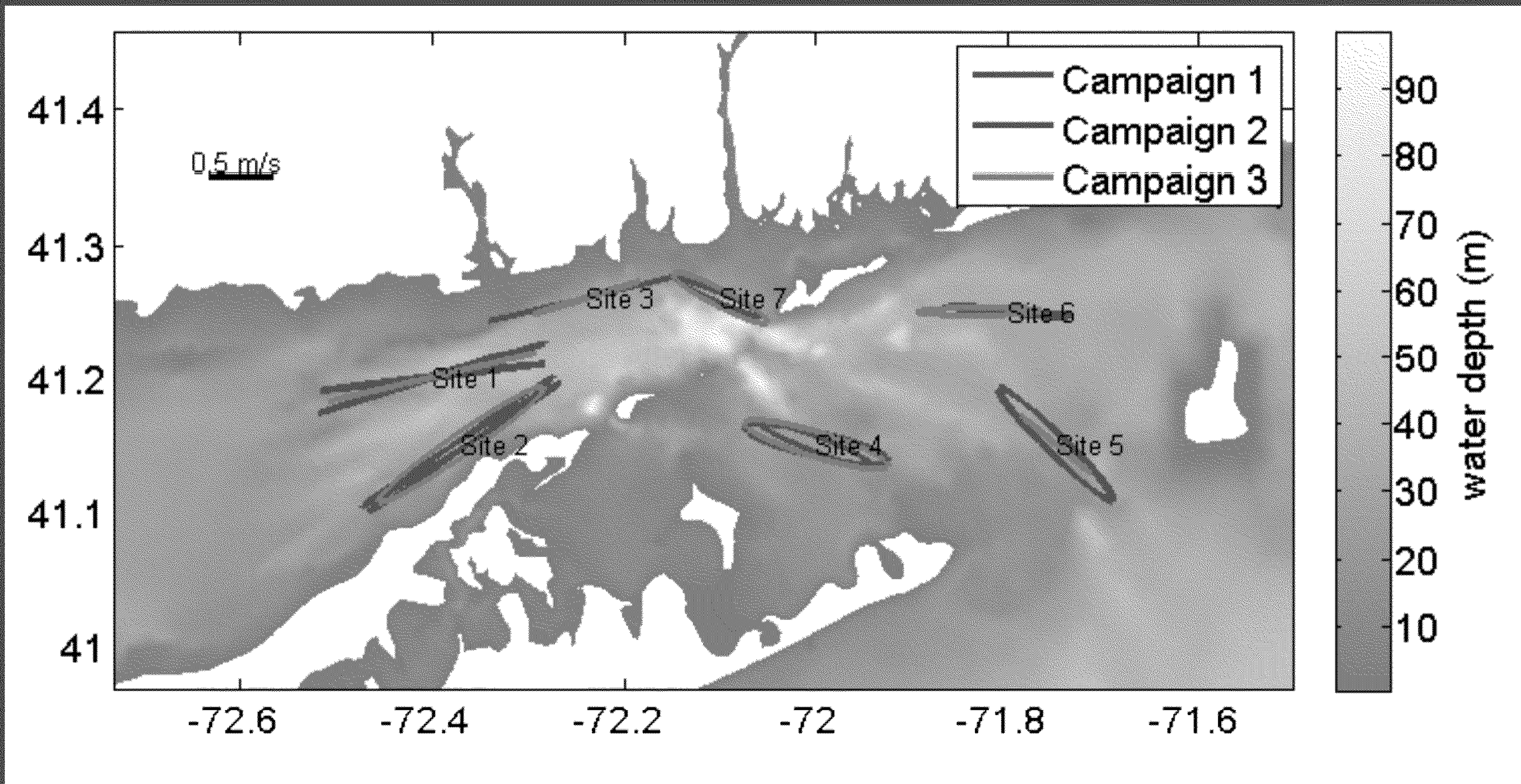
Nortek ADCP means at ~0.6m from seafloor



Mean velocity vectors at each moored station from the Nortek ADCP near the seafloor. The velocity scale is shown on graphic.

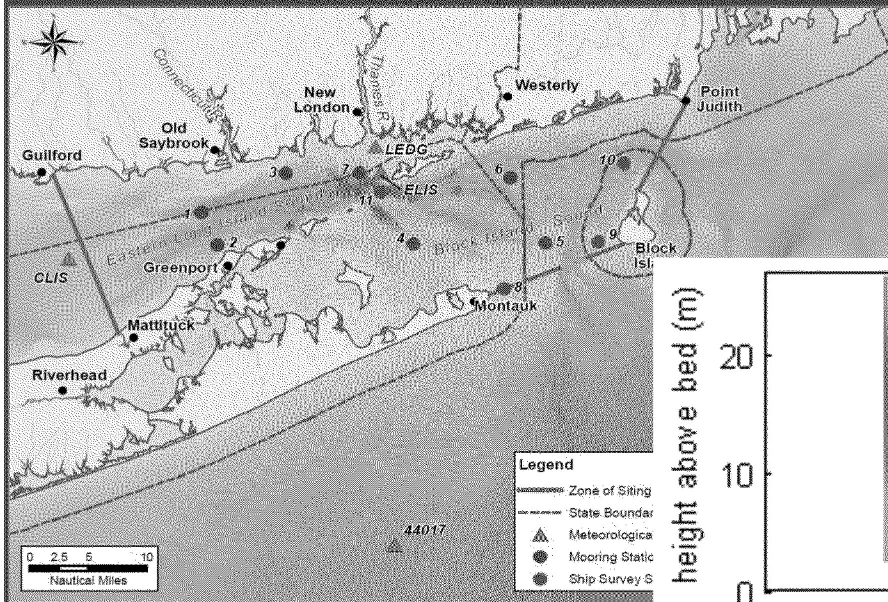
3. Evaluation – Field Program *(cont.)*

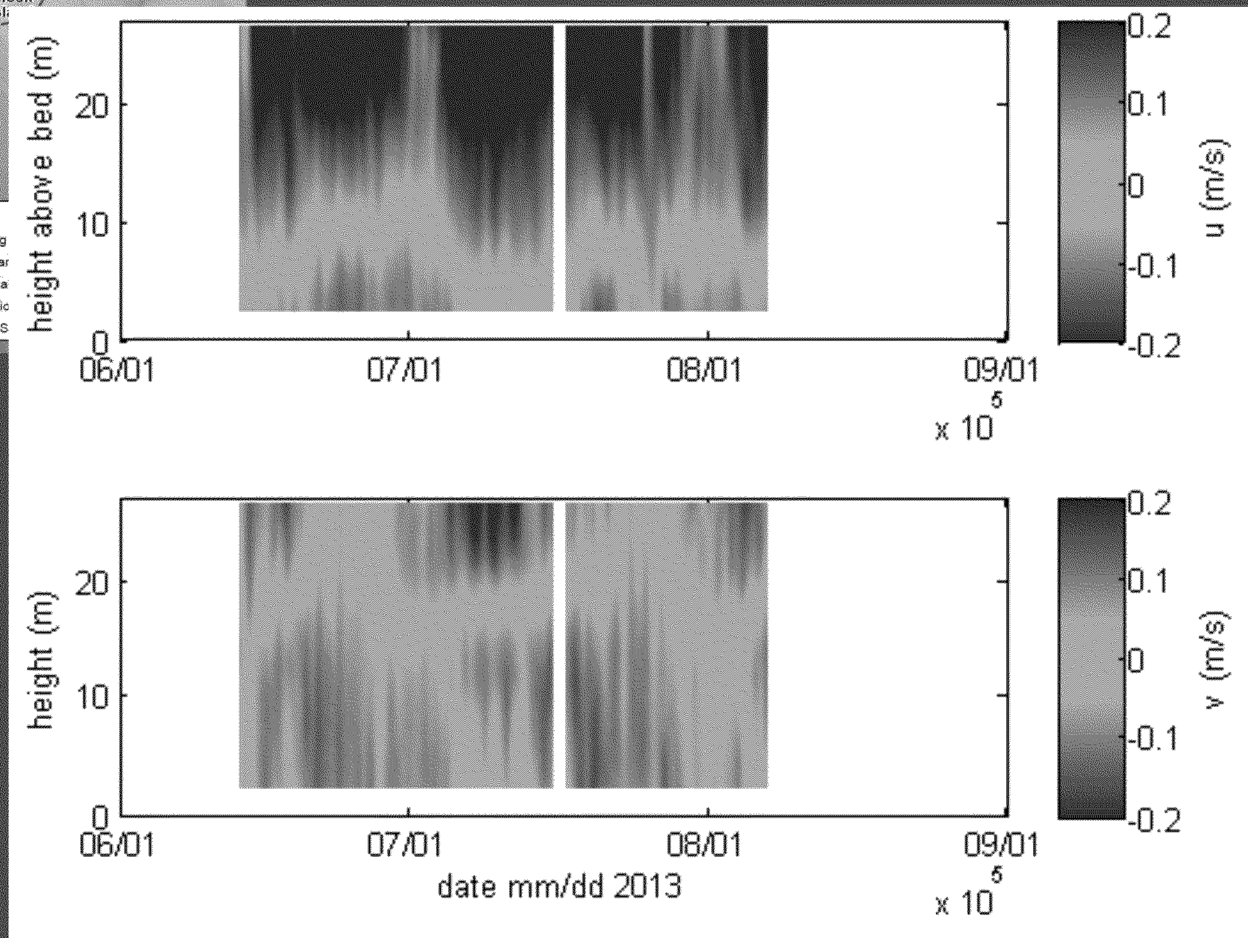
M2 Tidal Constituents



M2 ellipses for depth-average velocities from RDI ADCP measurements from the three campaigns (colors) and for FVCOM model (black) at all seven DOT stations. The grey shading represents mean water depth.

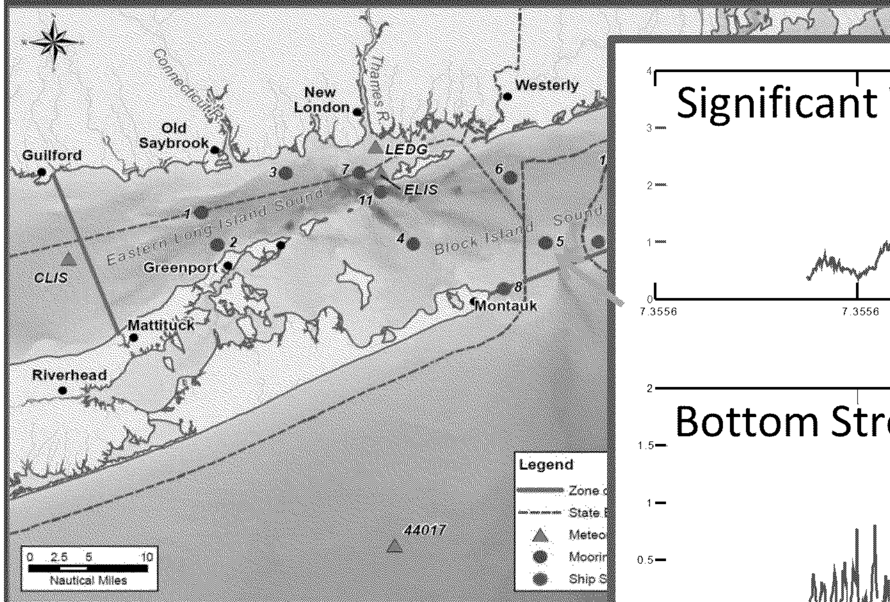
3. Evaluation – Field Program *(cont.)*

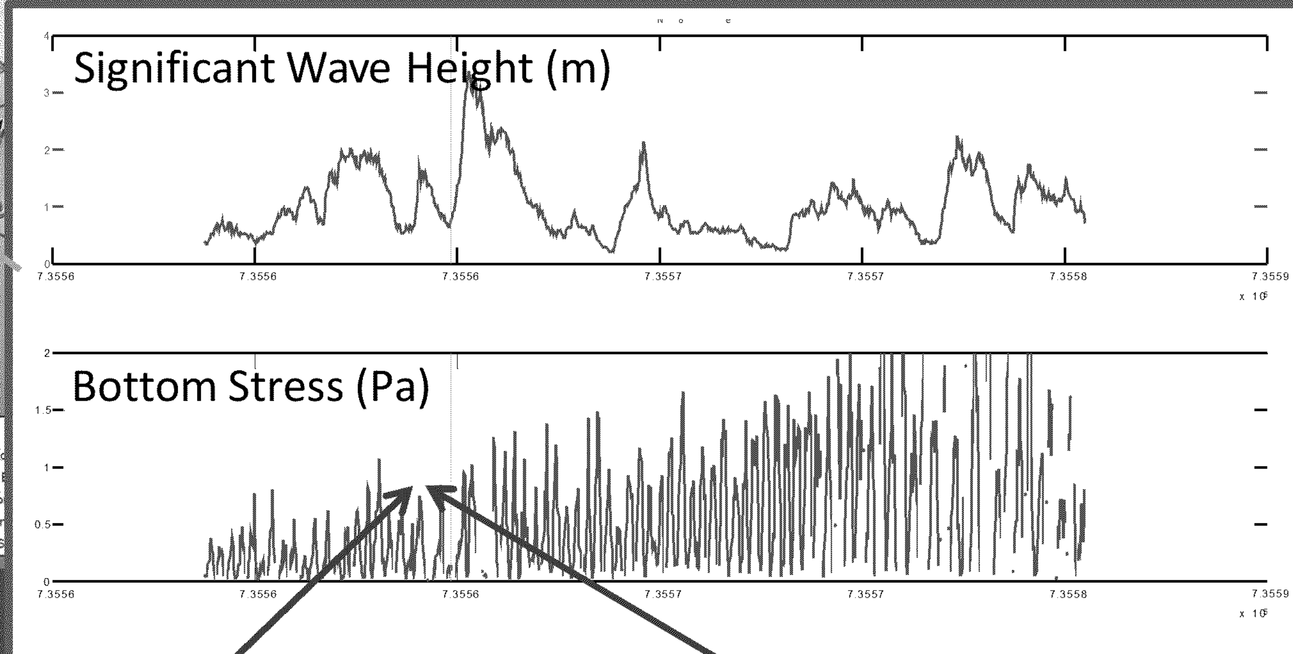


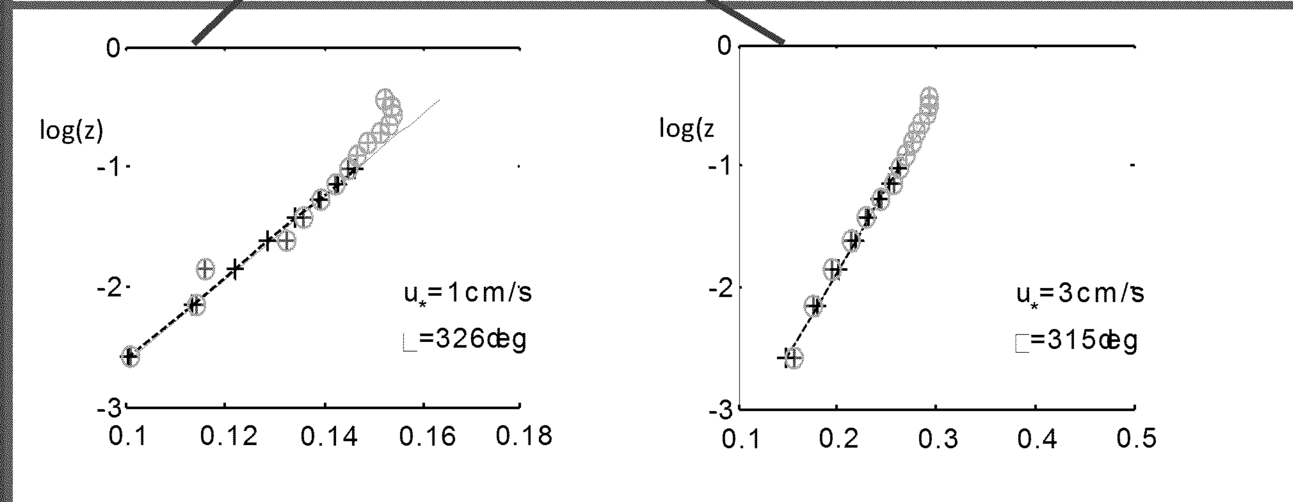


Low-pass filtered velocities for Station DOT5, Campaign 2. Eastward (upper graph) and northward (lower graph) components.

3. Evaluation – Field Program *(cont.)*







The variation of u(z) with log(z) for ensembles 297 and 317

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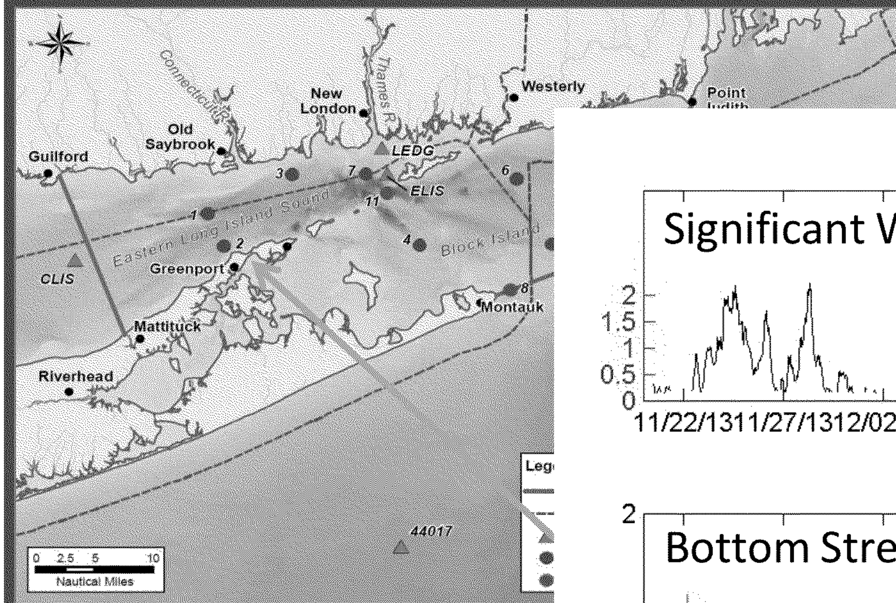
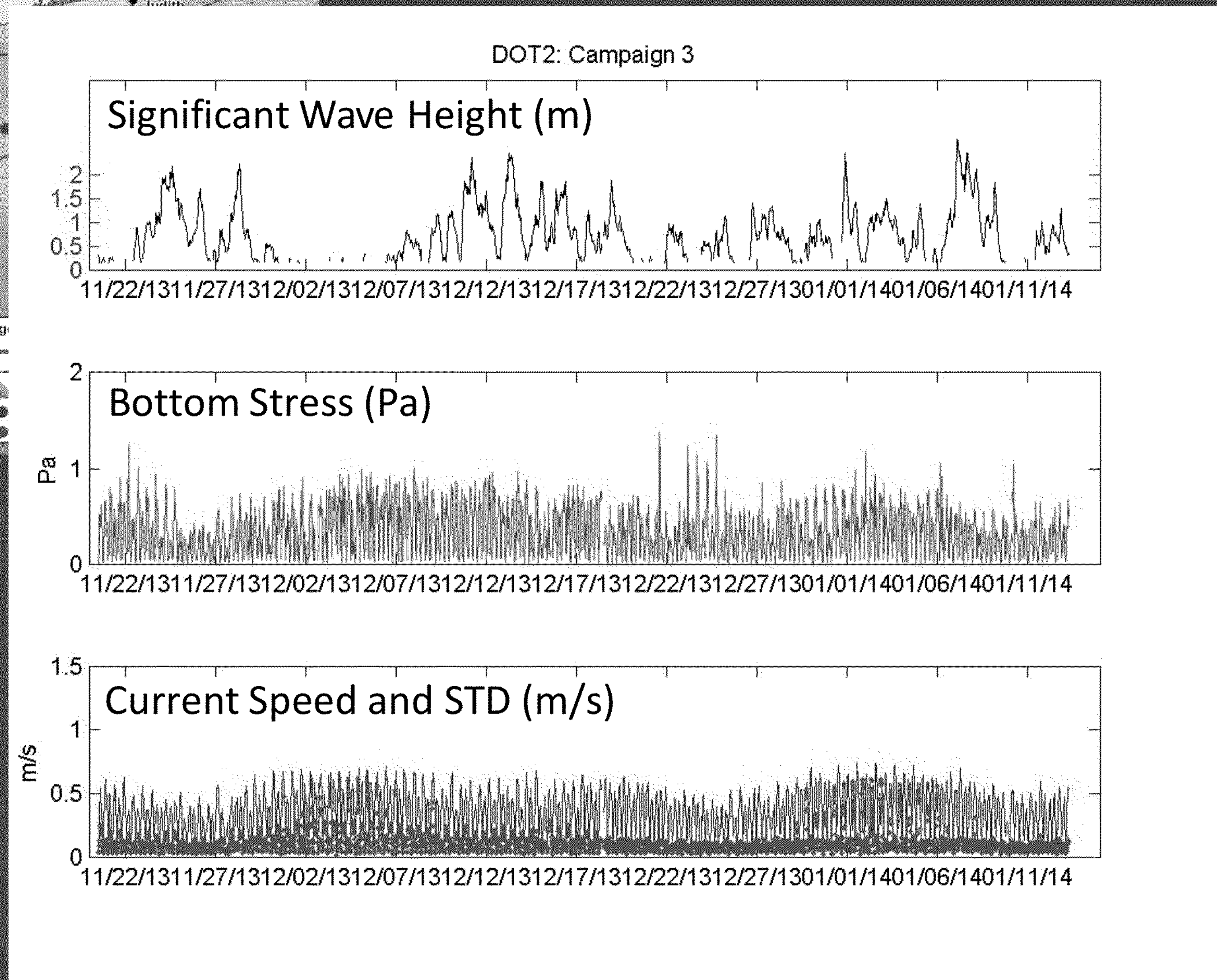
3. Evaluation – Field Program *(cont.)*

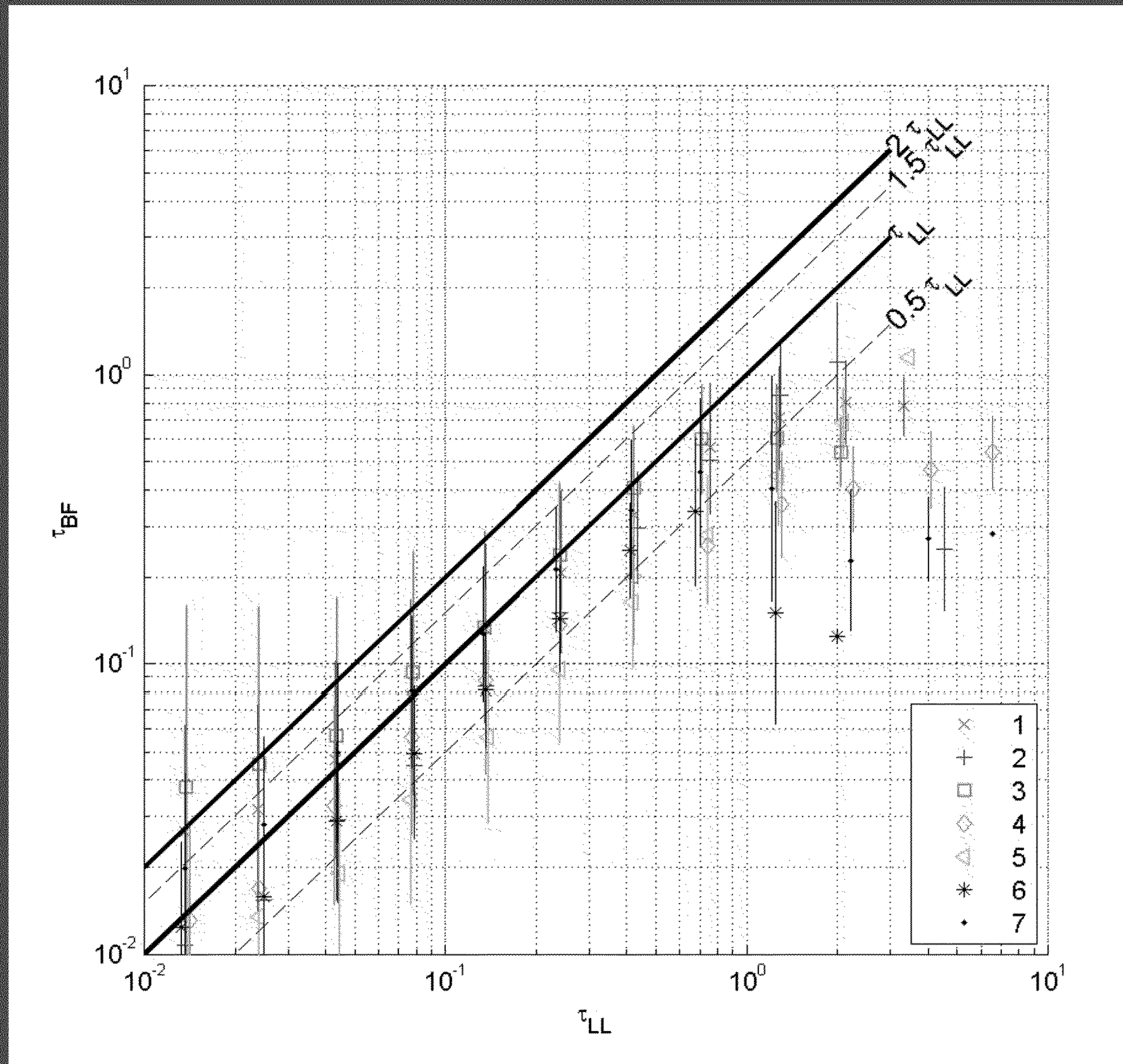




Characteristics at Station DOT2 during Campaign 3:
Top: Significant wave height (in m).
Middle: Stress.
Bottom: Standard deviation of velocity estimates within the ensemble (red line) and the ensemble means (blue line).

3. Evaluation – P e r f o r m a n c e

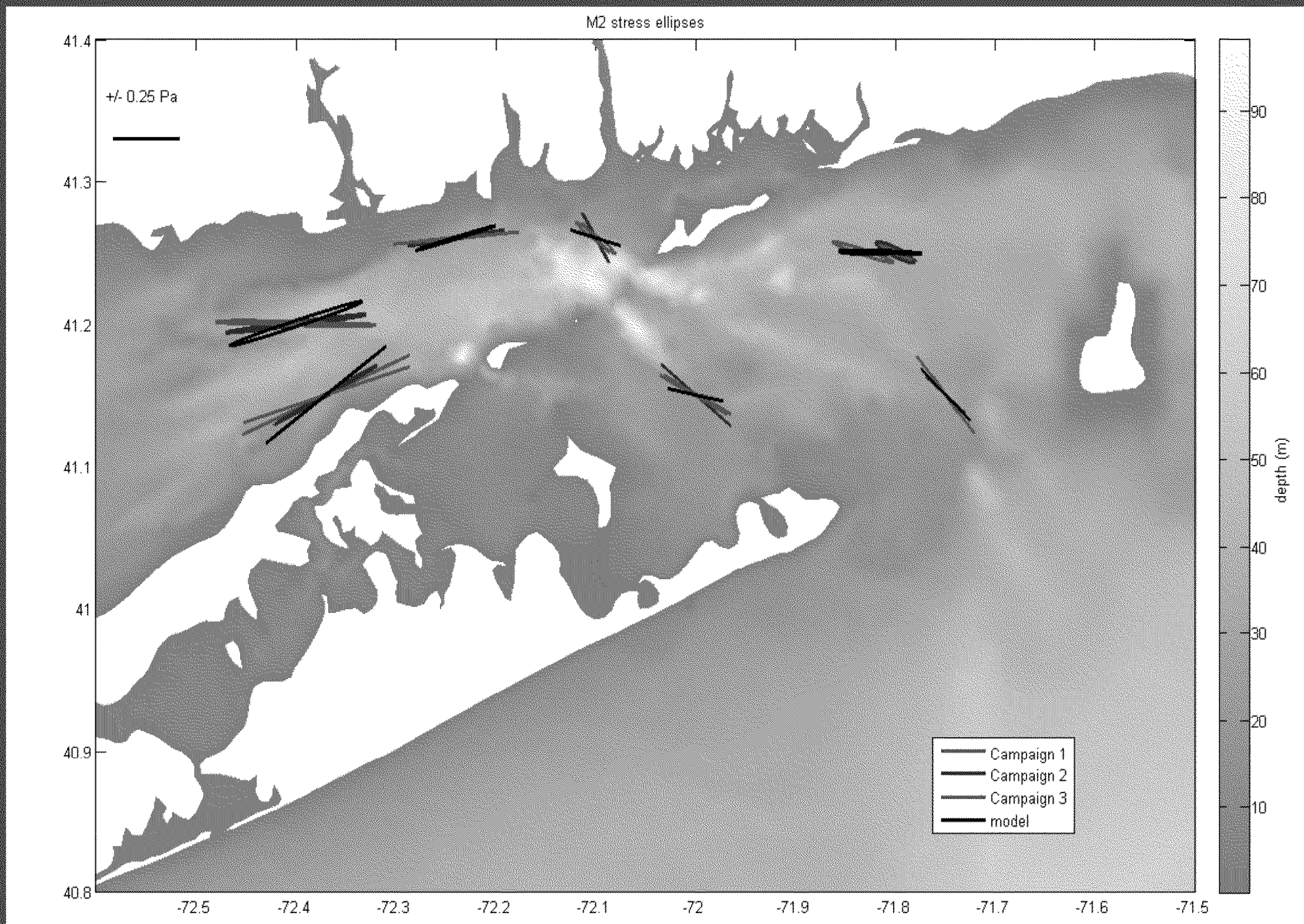
Measurements support the use of C_d =0.0025.



Summary of stress magnitude measurements using the log law and the bulk formula with C_d=0.0025. To suppress the noise inherent in turbulent quantities, measurements were bin-averaged. The key shows the stations numbers.

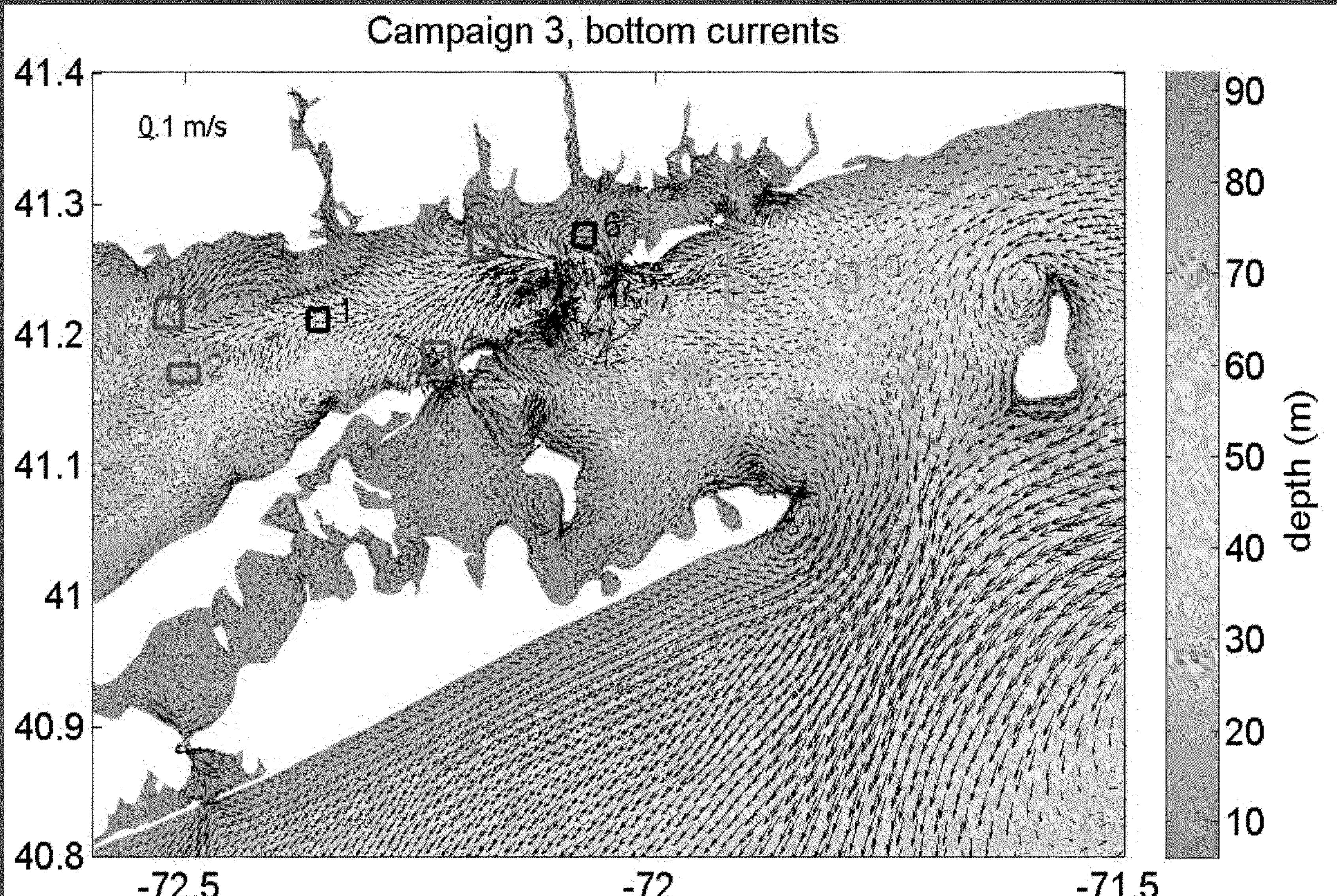
3. Evaluation – Performance *(cont.)*

Stress due to tides in data (color) and model (black) are in agreement



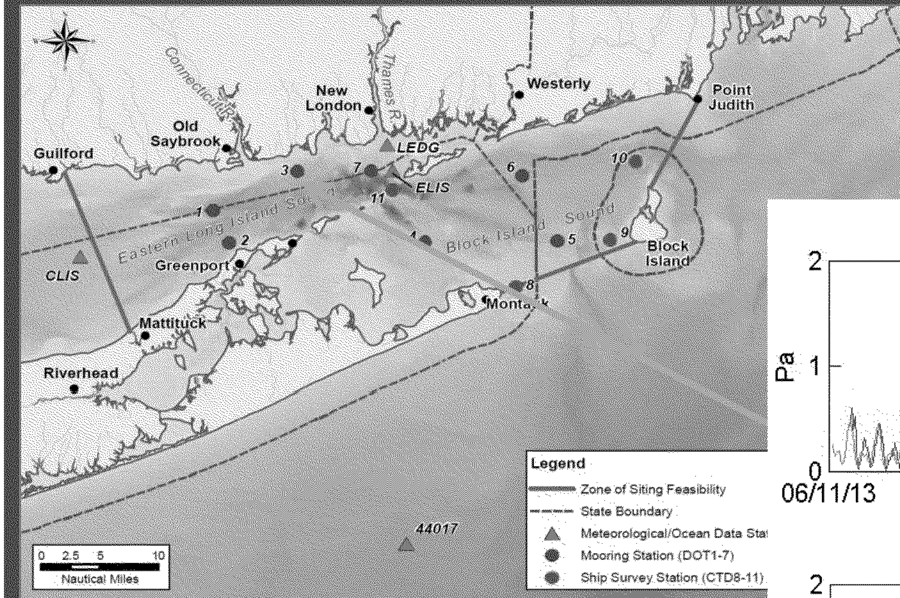
3. Evaluation – P e r f o r m a n c e *(cont.)*

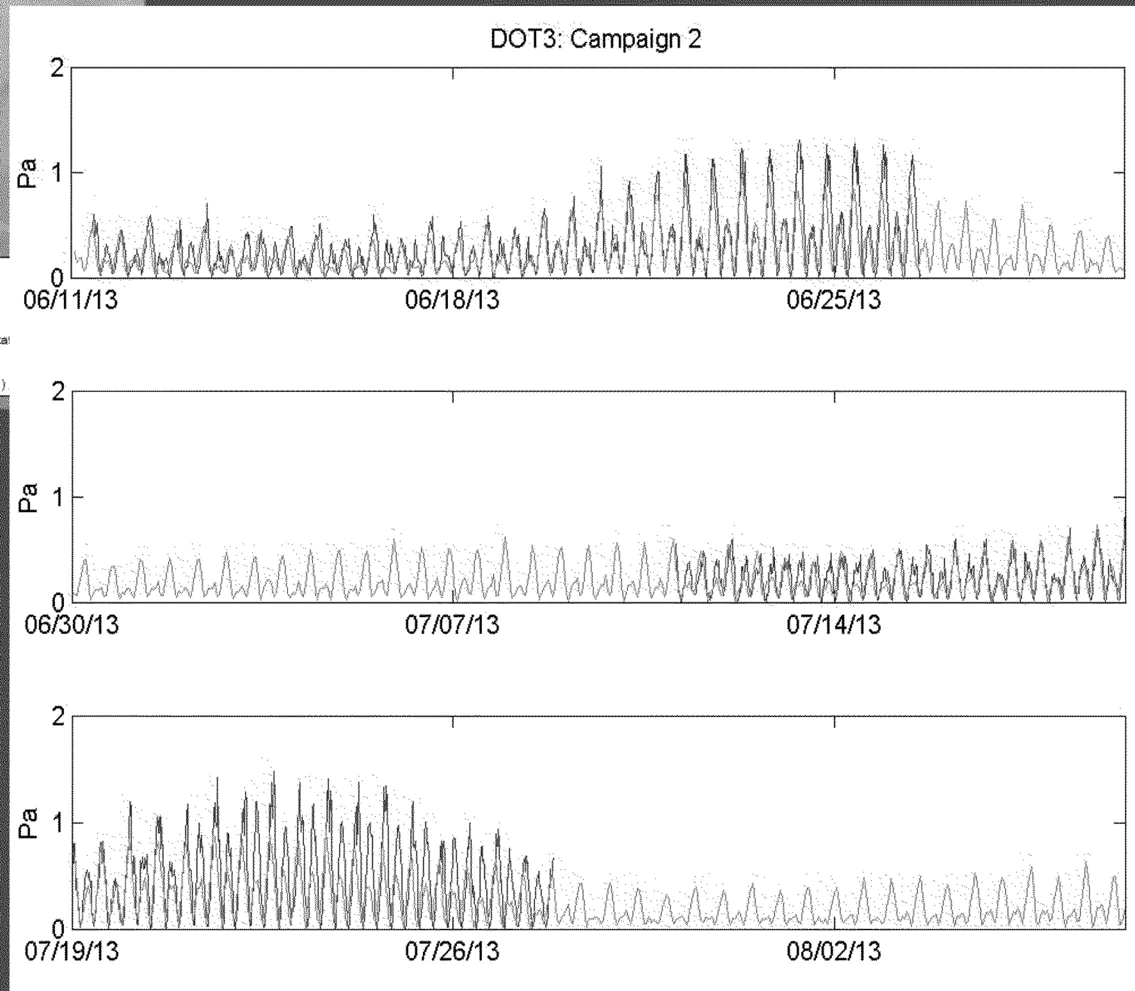
Model gets mean flow pattern correct



3. Evaluation – Performance *(cont.)*

Model simulations reproduce tidal and the spring-neap variations on observed stress

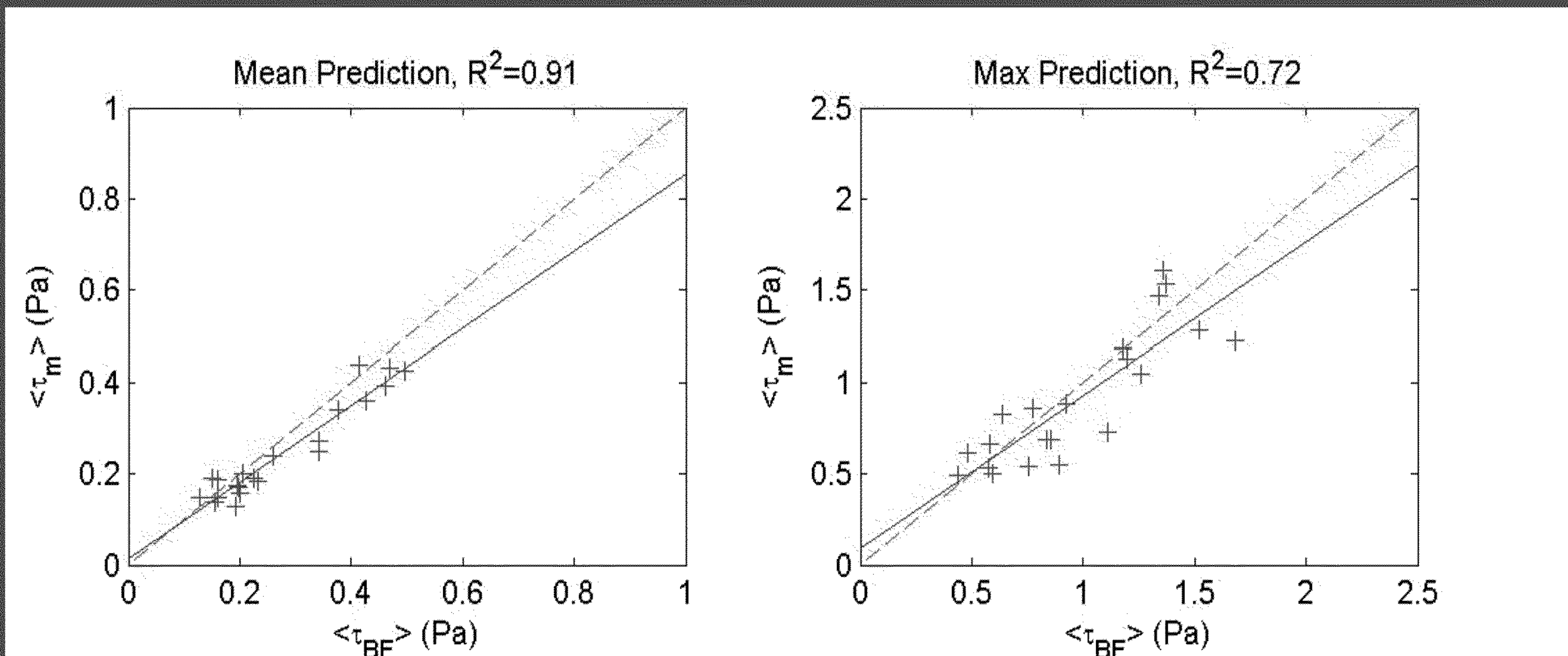




Model-predicted bottom stress at Station DOT3 during Campaign 2 in the summer of 2013 (magenta line). The blue line shows the measured stress using the bulk formula.

3. Evaluation – Performance (cont.)

- Model and observations agree on the campaign mean and maximum stress magnitudes.
- Model can effectively discriminate between places where the maximum measured stresses are large (>1 Pa) and those where they are smaller (<1Pa).



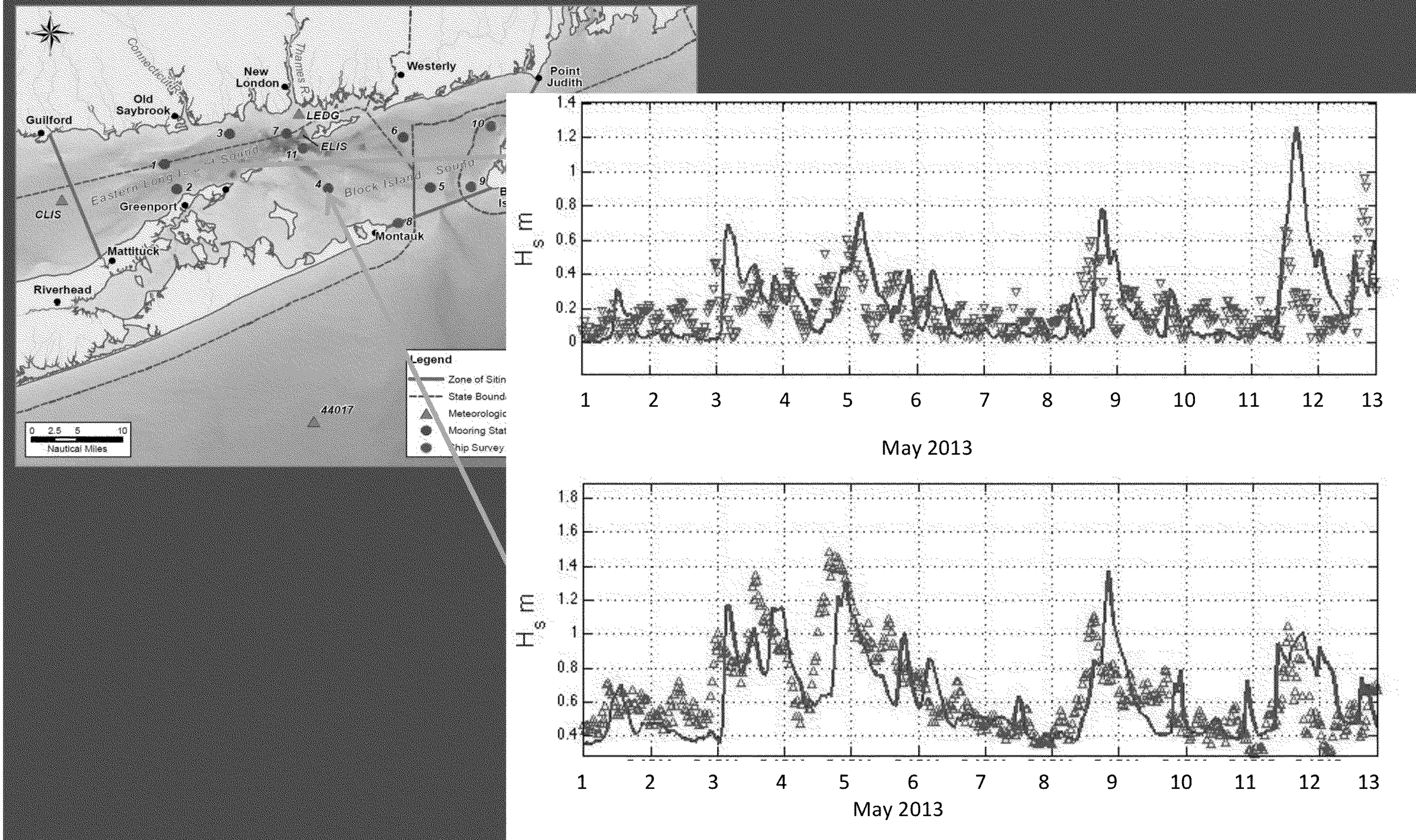
Left: Comparison of model predicted bottom stress magnitudes and mean bottom stress observed during the three campaigns. Points would all lie on the red dashed line if the model and data were in perfect agreement. The blue solid line shows the ordinary least-squares regression line which has a correlation coefficient of 0.91.
Right: Comparison of the predicted and observed maximum stress magnitudes. The correlation coefficient was 0.72.

3. Evaluation – Performance *(cont.)*

Model simulations reproduce tidal and spring-neap variations on observed stress

Station	Model Stress (Pa)		Observation Stress Magnitude					
	Mean	Max	Mean	Max	Correlation	Lag (hrs)	RMSE*	MAE**
Campaign 1								
DOT1	0.36	1.18	0.43	1.18	0.87	0.33	0.18	0.13
DOT2	0.43	1.28	0.50	1.52	0.85	0.33	0.24	0.16
DOT3	0.24	0.88	0.26	0.92	0.92	0.33	0.10	0.07
DOT4	0.17	0.50	0.20	0.60	0.89	0.38	0.07	0.05
DOT5	0.19	0.82	0.16	0.64	0.47	0.38	0.16	0.12
DOT6	0.15	0.49	0.13	0.44	0.86	-0.31	0.06	0.05
DOT7	0.14	0.69	0.16	0.84	0.65	0.67	0.12	0.08
Campaign 2								
DOT1	0.44	1.61	0.41	1.36	0.82	0.36	0.18	0.14
DOT2	0.39	1.22	0.46	1.68	0.67	0.67	0.28	0.20
DOT3	0.27	1.04	0.34	1.26	0.89	0.59	0.16	0.11
DOT4	0.19	0.55	0.23	0.89	0.83	0.76	0.12	0.09
DOT5	0.19	0.73	0.23	1.11	0.52	0.62	0.19	0.14
DOT6	0.19	0.62	0.15	0.48	0.84	0.42	0.08	0.06
DOT7	0.16	0.69	0.20	0.86	0.63	0.31	0.14	0.10
Campaign 3								
DOT1	0.34	1.47	0.38	1.34	0.79	0.84	0.19	0.13
DOT2	0.43	1.53	0.47	1.37	0.72	1.00	0.26	0.19
DOT3	0.25	1.12	0.34	1.20	0.83	0.50	0.17	0.11
DOT4	0.17	0.66	0.20	0.58	0.81	0.76	0.09	0.06
DOT5	0.20	0.86	0.21	0.77	0.65	-2.19	0.14	0.10
DOT6	0.15	0.53	0.16	0.58	0.66	0.16	0.09	0.06
DOT7	0.13	0.54	0.19	0.75	0.68	0.50	0.16	0.11

3. Evaluation – P e r f o r m a n c e *(cont.)*



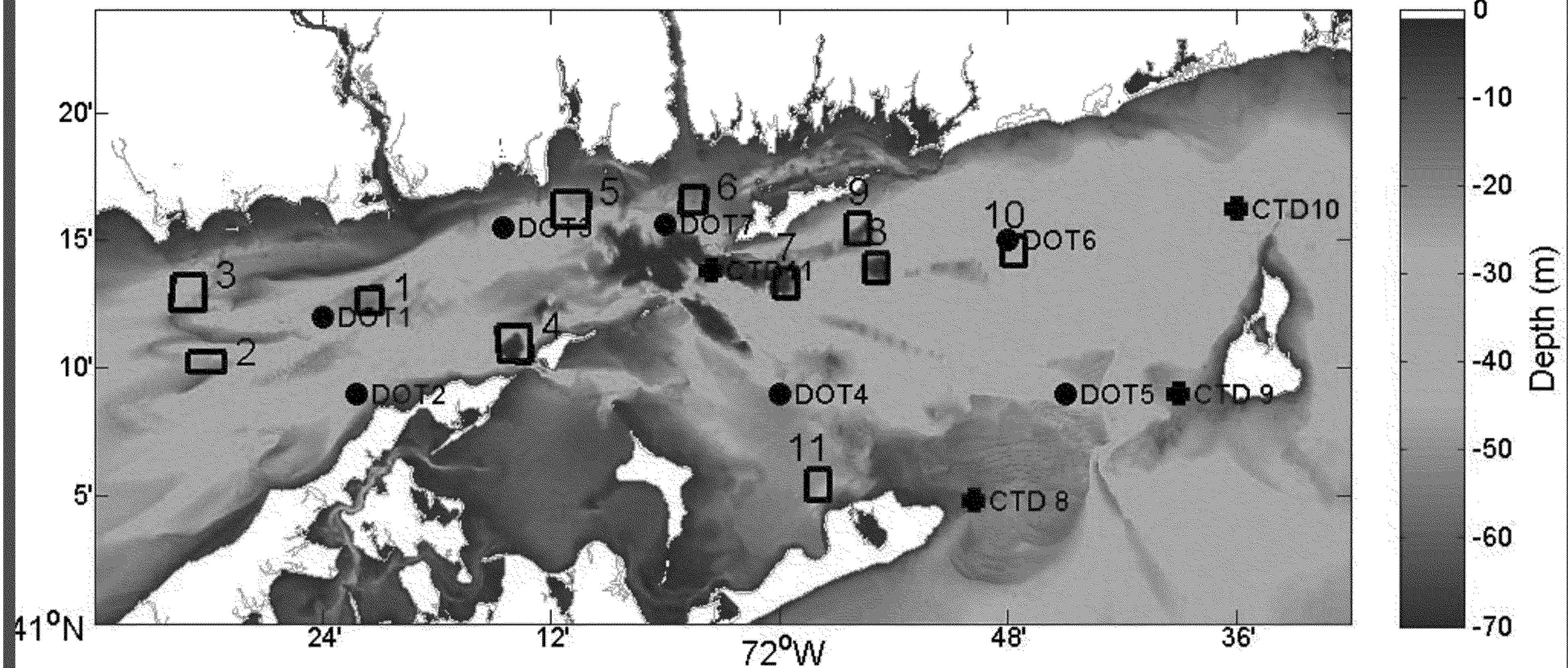
Comparison of model and observed significant wave height at Stations DOT1 (upper panel) and DOT4 (lower panel) during May 2013.

4. Analysis

- Find maximum bottom stress magnitude at each point in the ZSF in the three Campaigns
- Compare values at sites identified in the screening process
- Simulate period of a severe storm (Superstorm Sandy) and compare maximum stress magnitudes

4. Analysis *(cont.)*

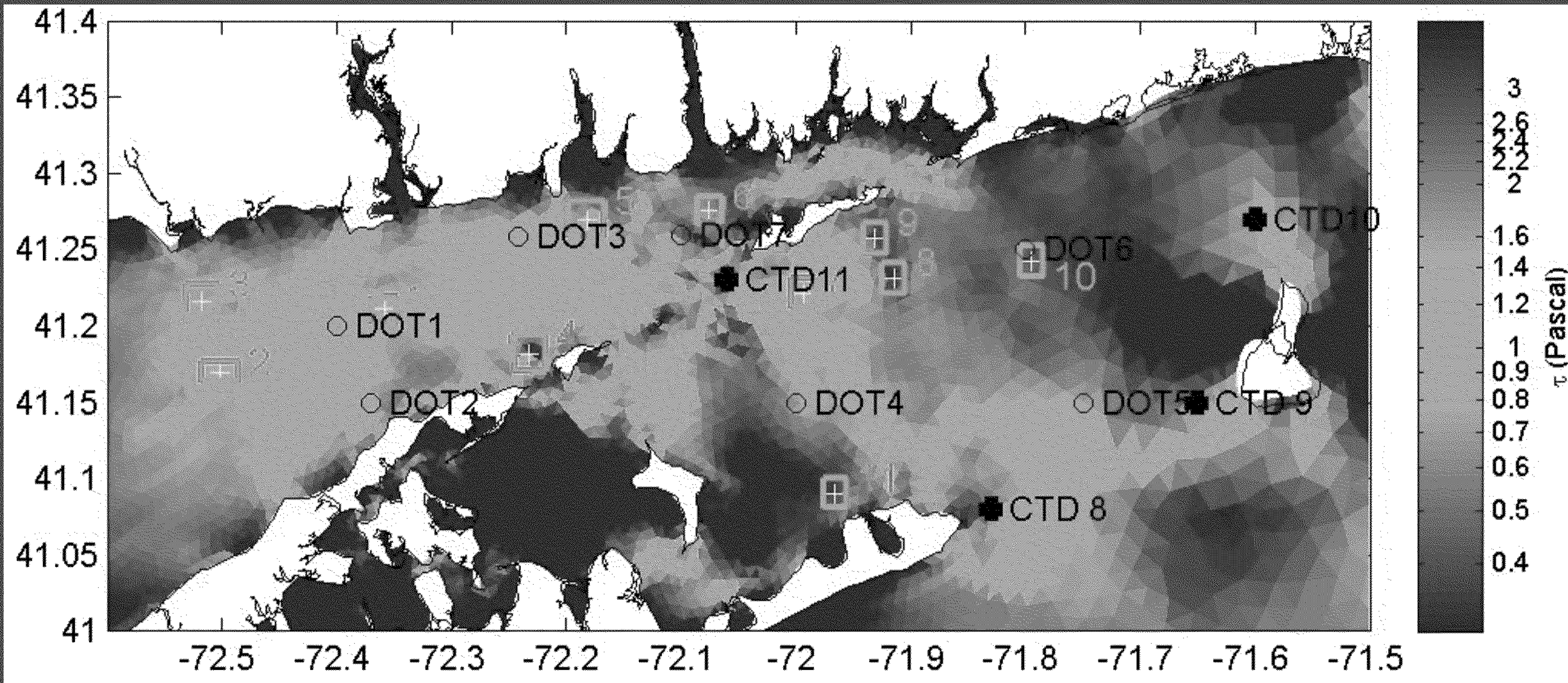
Bathymetry and locations of potential sites



Water depth and 11 potential dredged material disposal sites (open boxes) as identified during the initial screening process. Sites 1 and 6 are the active disposal sites (CSDS and NLDS, respectively). The seven mooring stations ('DOT') are identified by full circles; the four additional ship survey stations ('CTD') are identified by crosses.

4. Analysis *(cont.)*

- Spatial differences are much larger than seasonal variations
- Stress is high in much of ZSF

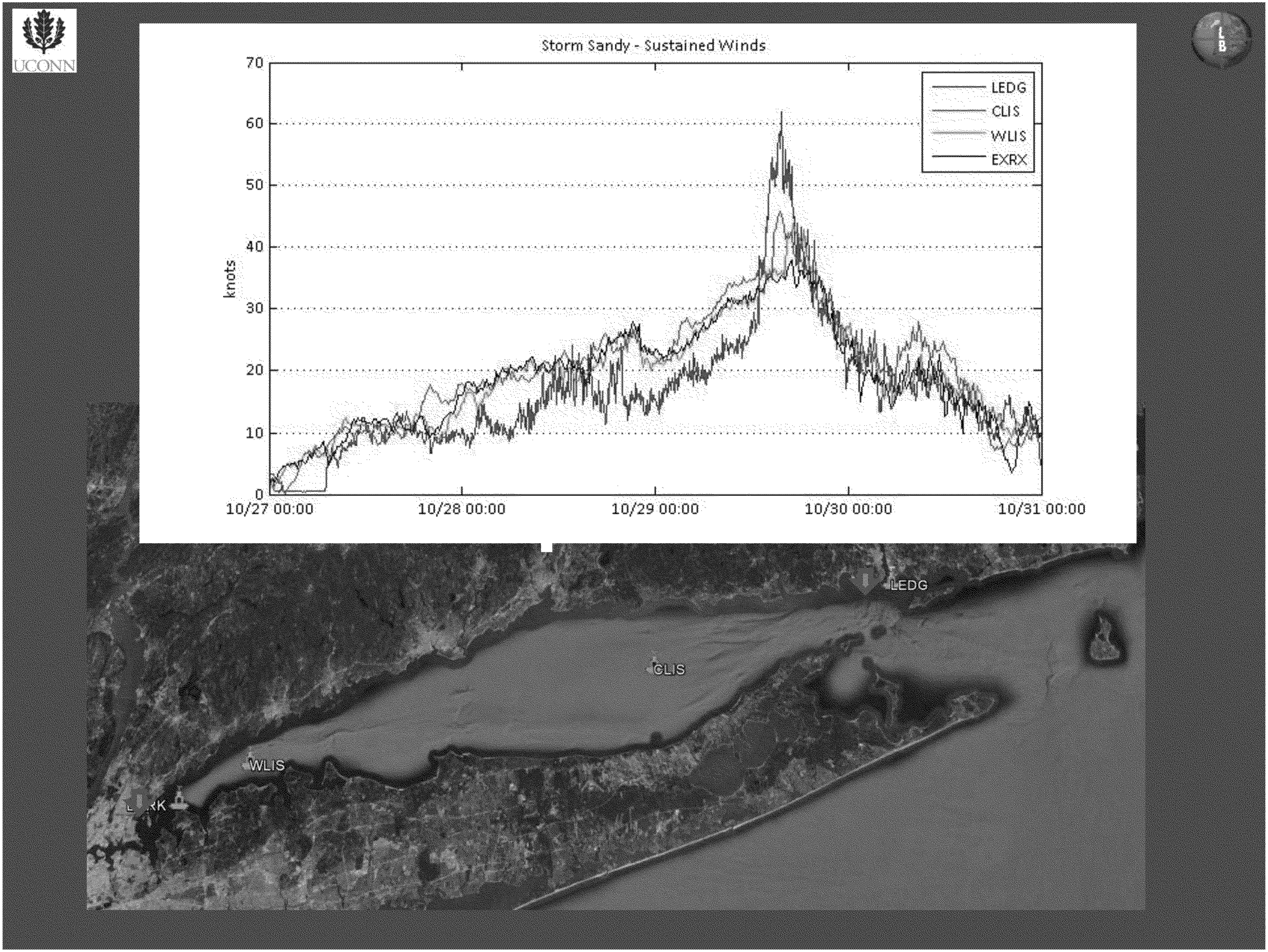


Maximum bottom stress during Campaign 3 (November 20, 2013, to January 16, 2014) for storm conditions (i.e., due to the principal tidal current constituents and the seasonal mean flow, as well as wind).

4. Analysis *(cont.)*

Maximum Bottom Stress (Pa) during Storm Conditions at Potential Dredged Material Disposal Sites

Potential Disposal Site			Maximum Bottom Stress (Pa)			Change in Maximum Bottom Stress during Storm Conditions relative to Fair-weather Conditions		
			1. (spring)	2. (summer)	3. (winter)	1. (spring)	2.(summer)	3. (winter)
ELIS	1	Cornfield Shoals Disposal Site	1.17	1.31	1.24	-7%	-8%	-5%
	2	Six Mile Reef Disposal Site	0.92	1.09	1.00	-7%	6%	-8%
	3	Clinton Harbor Disposal Site	0.72	0.71	0.81	6%	14%	1%
	4	Orient Point Disposal Site	0.52	0.61	0.48	61%	21%	7%
	5	Niantic Bay Disposal Site	0.73	0.97	0.84	-8%	19%	-2%
	6	New London Disposal Site	0.60	0.70	0.69	33%	31%	29%
BIS	7	Fishers Island-west	0.79	0.91	0.86	-5%	8%	17%
	8	Fishers Island-east	0.49	0.51	0.39	12%	-5%	-9%
	9	Fishers Island-center	0.39	0.50	0.38	20%	36%	15%
	10	Block Island Sound Disposal Site	0.49	0.63	0.44	6%	9%	-12%
	11	North of Montauk	0.31	0.31	0.34	0%	5%	-7%


UCONN
Storm Sandy - Sustained Winds
70
60
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40
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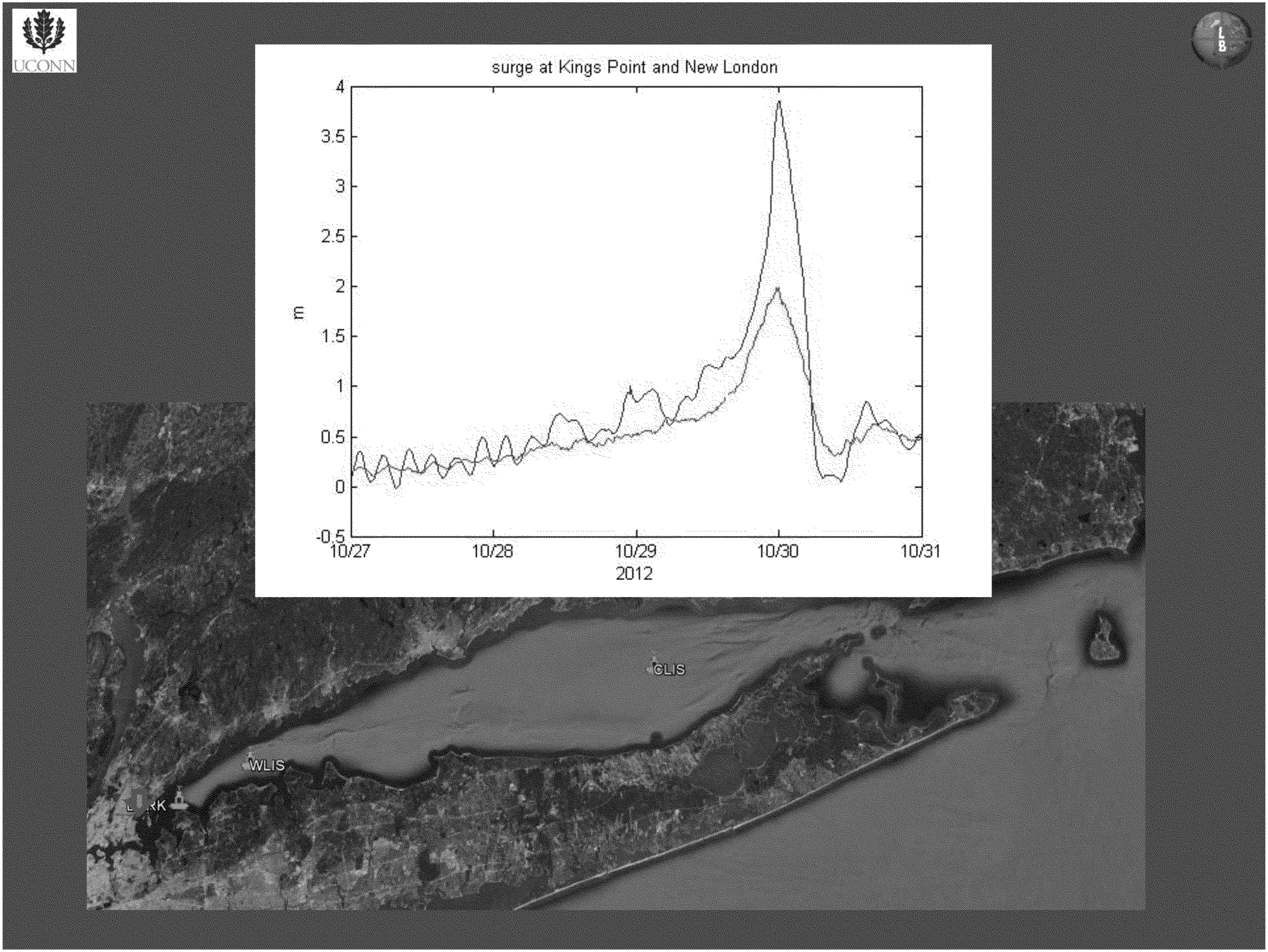
UCONN
surge at Kings Point and New London
m
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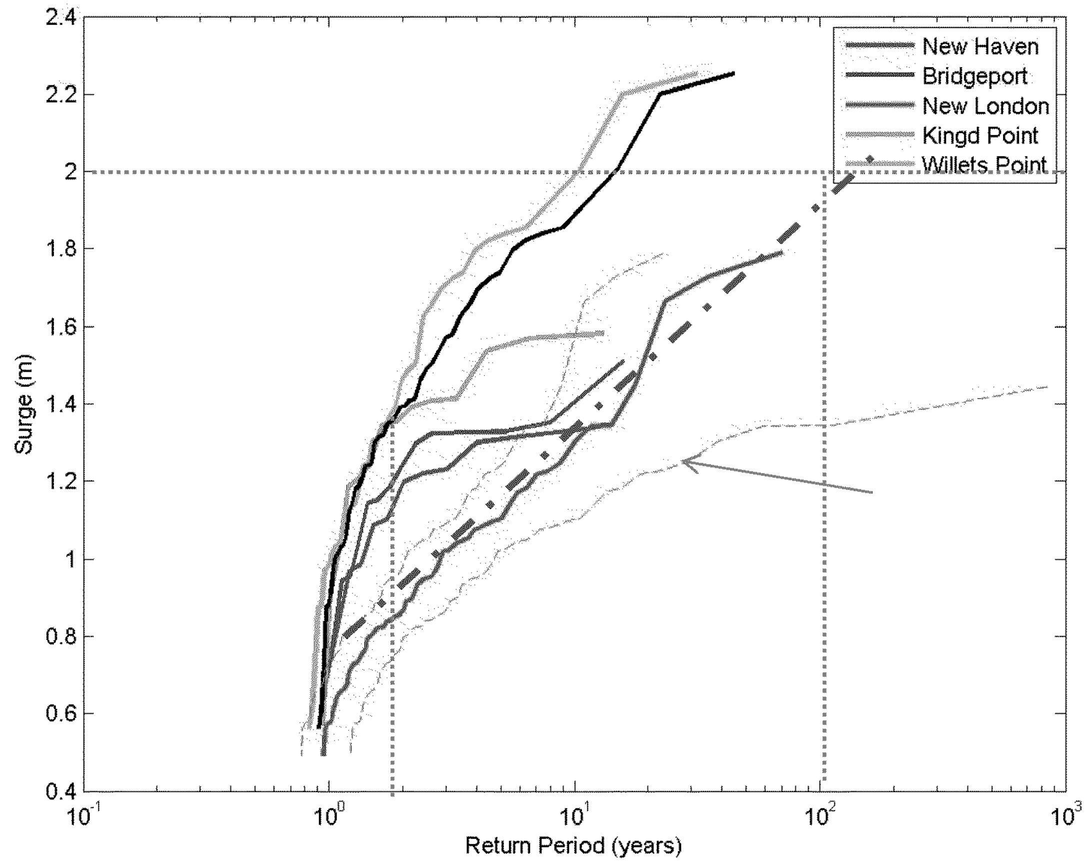
2012
CLIS
WLIS

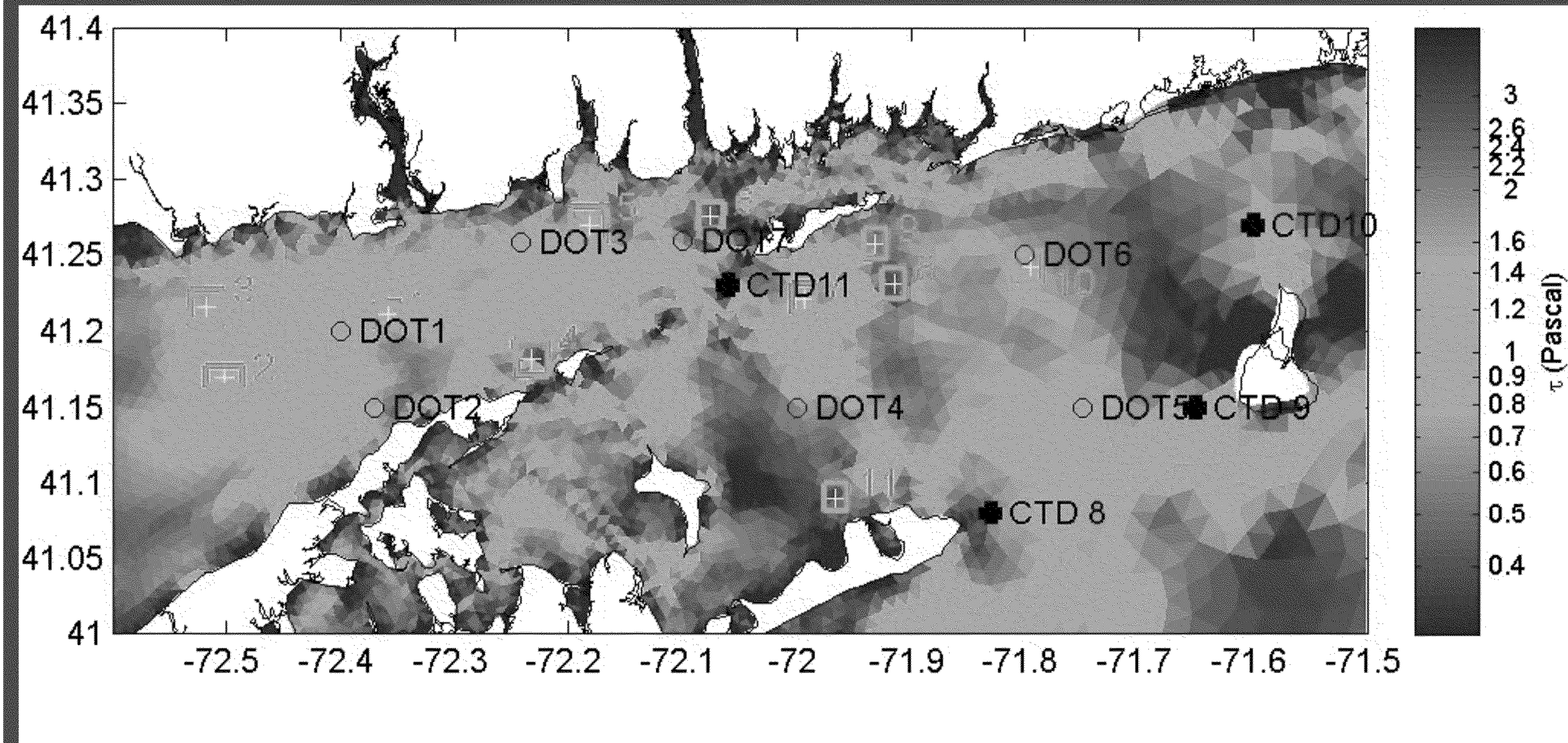
Using NOAA Sea Level data to 2012



Sandy surge return period is ~100 years at New London

4. Analysis *(cont.)*

Superstorm Sandy created higher maximum bottom stresses in some areas and lower stresses in other areas



Maximum bottom stress simulated for the period October 28 to 31, 2012 when Superstorm Sandy passed over New England.

4. Analysis *(cont.)*

Potential Disposal Site			Superstorm Sandy Conditions		
			Bottom Stress (Pa)	Change in Bottom Stress in 'Sandy' relative to Fair-weather Conditions in Campaign 3	Change in Bottom Stress in 'Sandy' relative to Storm Conditions in Campaign 3
ELIS	1	Cornfield Shoals Disposal Site	1.16	-11%	-6%
	2	Six Mile Reef Disposal Site	1.26	16%	25%
	3	Clinton Harbor Disposal Site	0.87	9%	8%
	4	Orient Point Disposal Site	0.53	17%	9%
	5	Niantic Bay Disposal Site	0.99	16%	19%
	6	New London Disposal Site	0.48	-10%	-30%
BIS	7	Fishers Island-west	1.17	58%	35%
	8	Fishers Island-east	0.46	5%	16%
	9	Fishers Island-center	0.55	69%	47%
	10	Block Island Sound Disposal Site	0.73	49%	68%
	11	North of Montauk	0.39	6%	14%

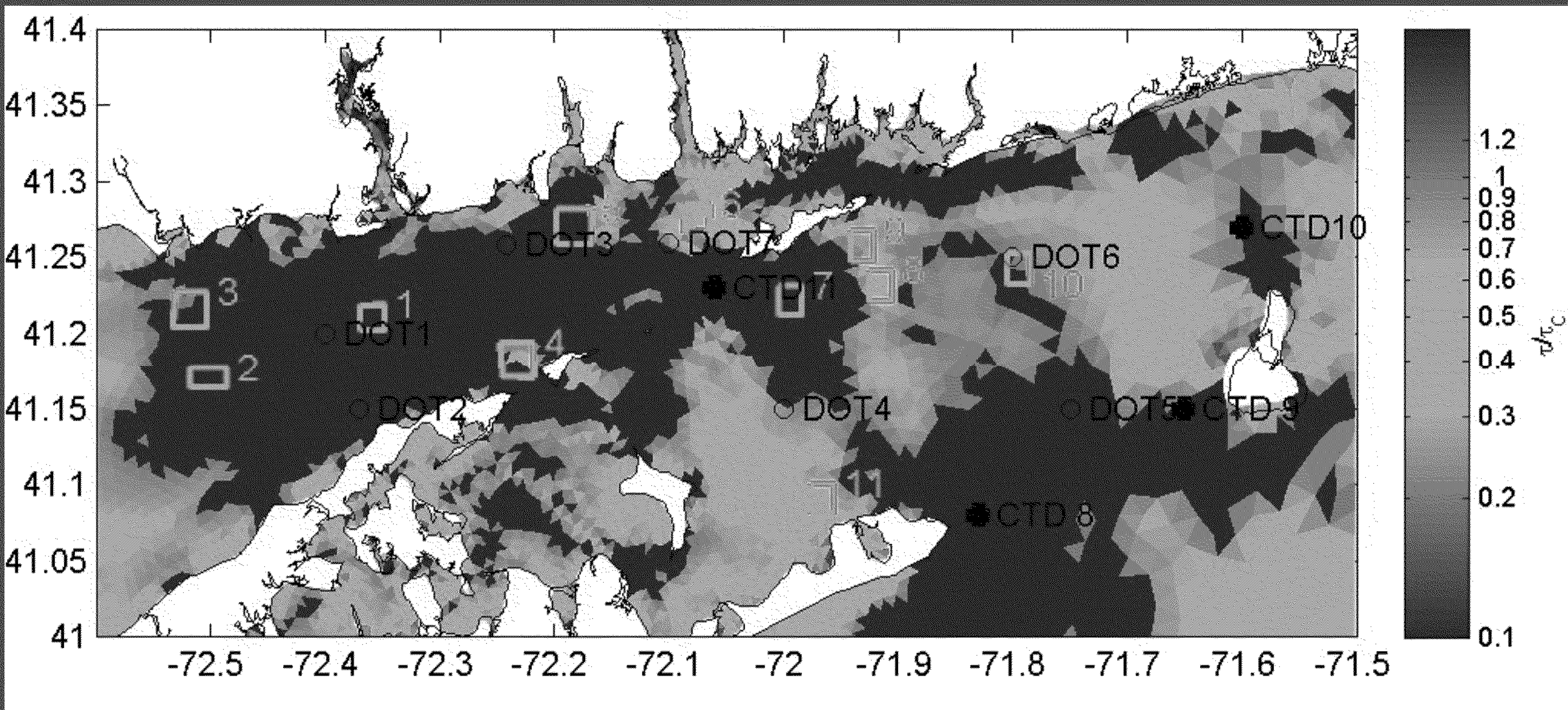
4. Analysis *(cont.)*

Stress Threshold for Erosion on Seafloor:

- Defined as the level of stress at which dredged material in a disposal area will be mobilized
- Depends upon sediment grain size, fraction of clay, volume fraction, level cohesiveness
- Based on a review of the literature, we choose 0.75 Pa as the design threshold

4. Analysis *(cont.)*

Brown areas show values of maximum bottom stress greater than threshold.



Areas with maximum bottom stress exceeding the 0.75 Pa threshold during the simulation of Superstorm Sandy (screened as a uniform brown layer). Areas with bottom stress below 0.75 Pa are scaled (see color key on the right).

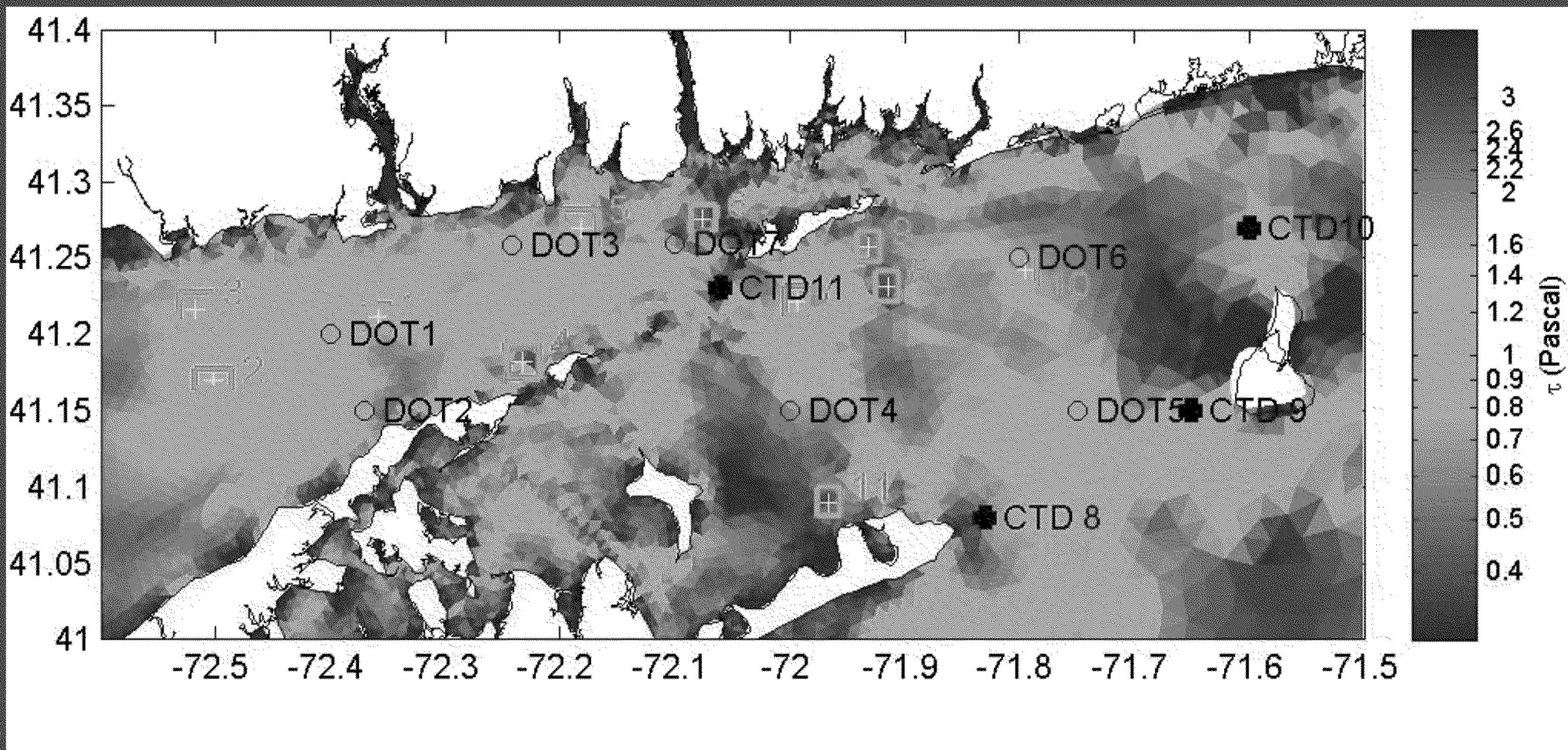
4. Analysis *(cont.)*

Comparison of Maximum Bottom Stress (Pa) for Potential Dredged Material Disposal Sites in the simulations of the three Observation Campaigns and Superstorm Sandy.

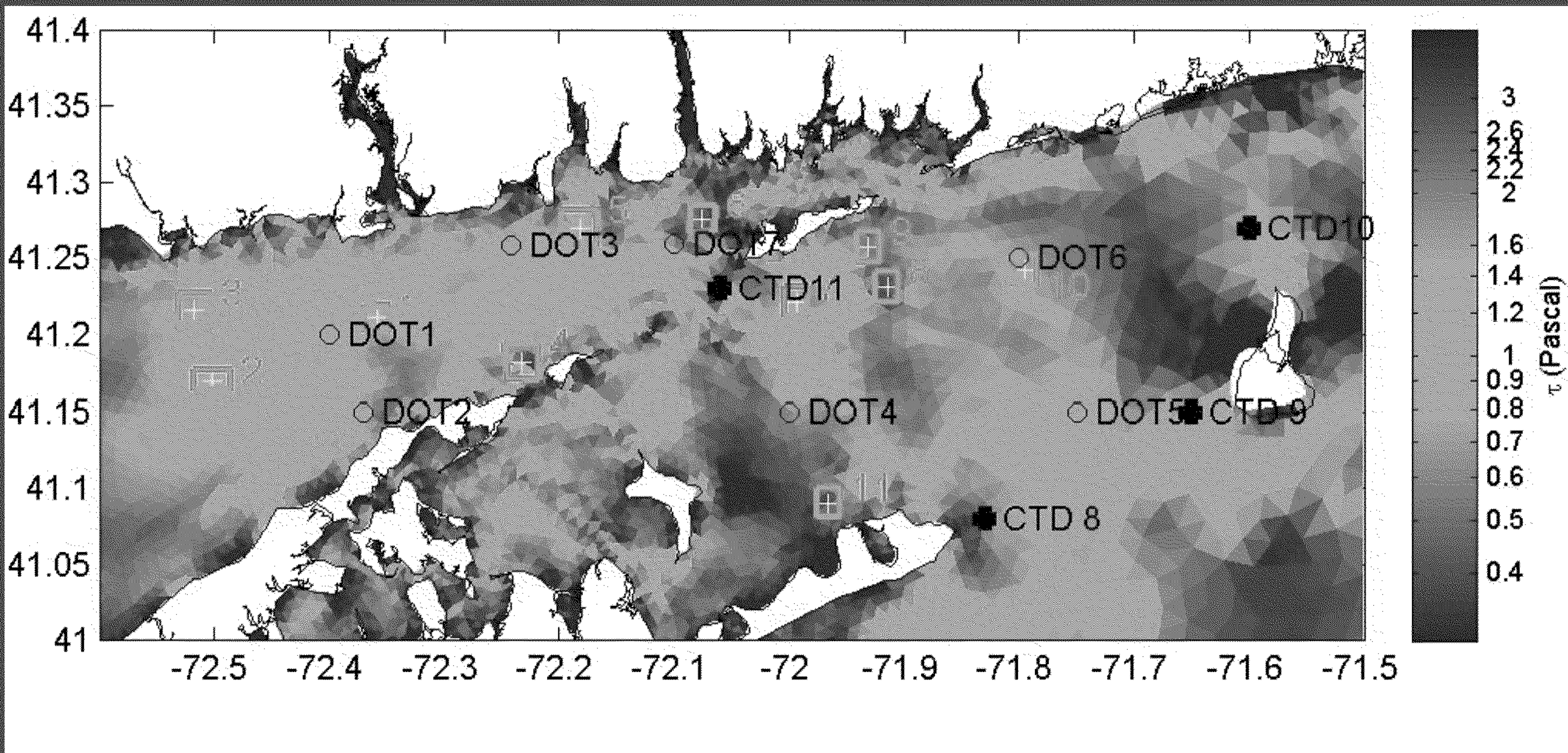
Potential Disposal Site				Maximum Stress in Simulations (Pa)	
ELIS	BIS	No.	Site Name	Group	Highest Value
□		1	Cornfield Shoals Disposal Site	>1	1.31
□		2	Six Mile Reef Disposal Site		1.26
	□	7	Fishers Island-west Disposal Site		1.17
□		5	Niantic Bay Disposal Site	0.75-1.0	0.99
□		3	Clinton Harbor Disposal Site		0.87
	□	10	Block Island Sound Disposal Site	<0.75	0.73
□		6	New London Disposal Site		0.69
	□	9	Fishers Island-center		0.55
□		4	Orient Point Disposal Site		0.53
	□	8	Fishers Island-east		0.46
	□	11	North of Montauk		0.39

5. Summary

- Model results explain measured bottom stress variations in space and time with errors that are substantially less than the differences between the maximum stresses at the 7 field sites.
- **Site 6 (New London DS)** is the only site in Eastern Long Island Sound with maximum bottom stress below the 0.75 Pa threshold.
-



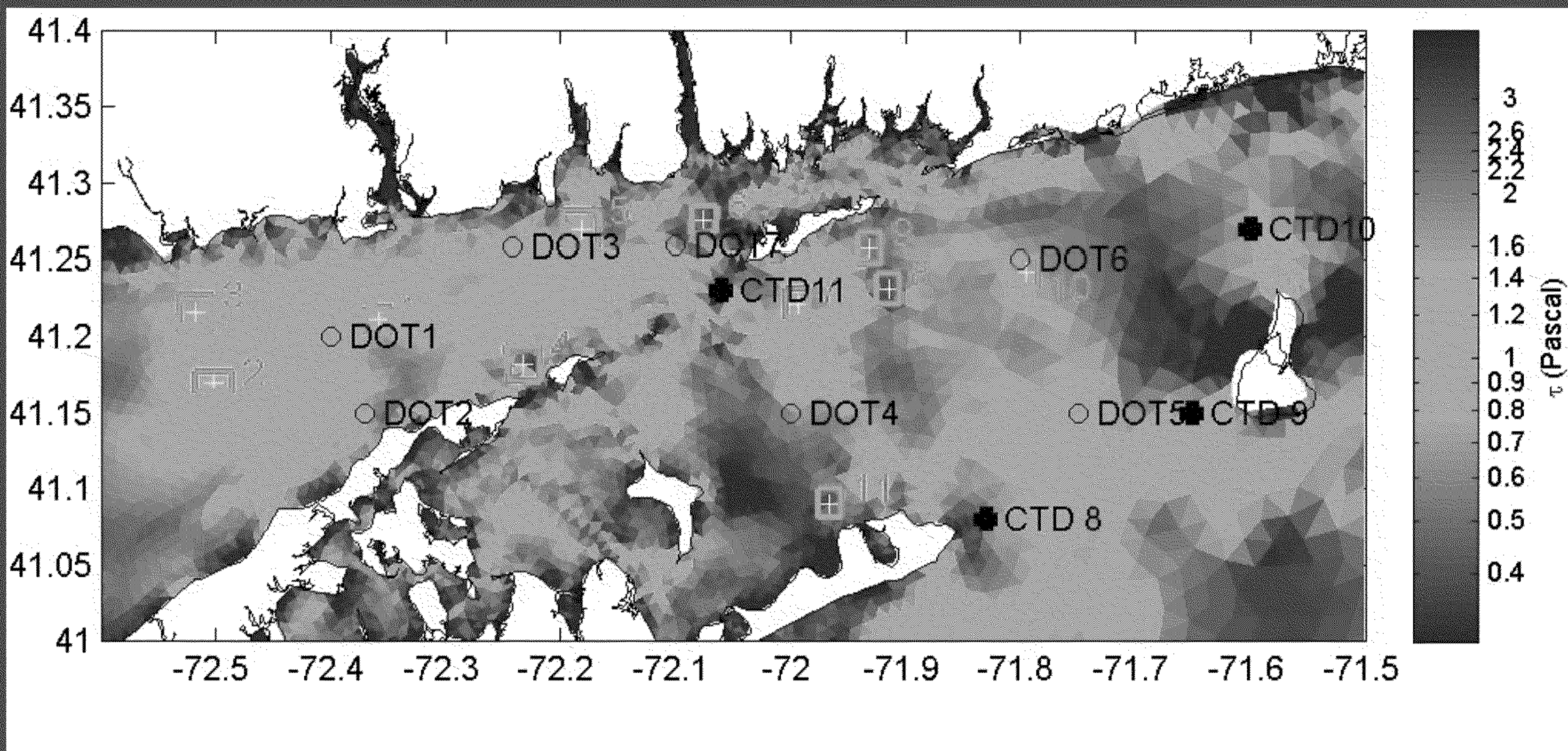
- **Sites 8, 9 and 11 (Fishers Island center and east, and North of Montauk)** in Block Island Sound show maximum bottom stress below 0.75 Pa threshold.



5. Summary

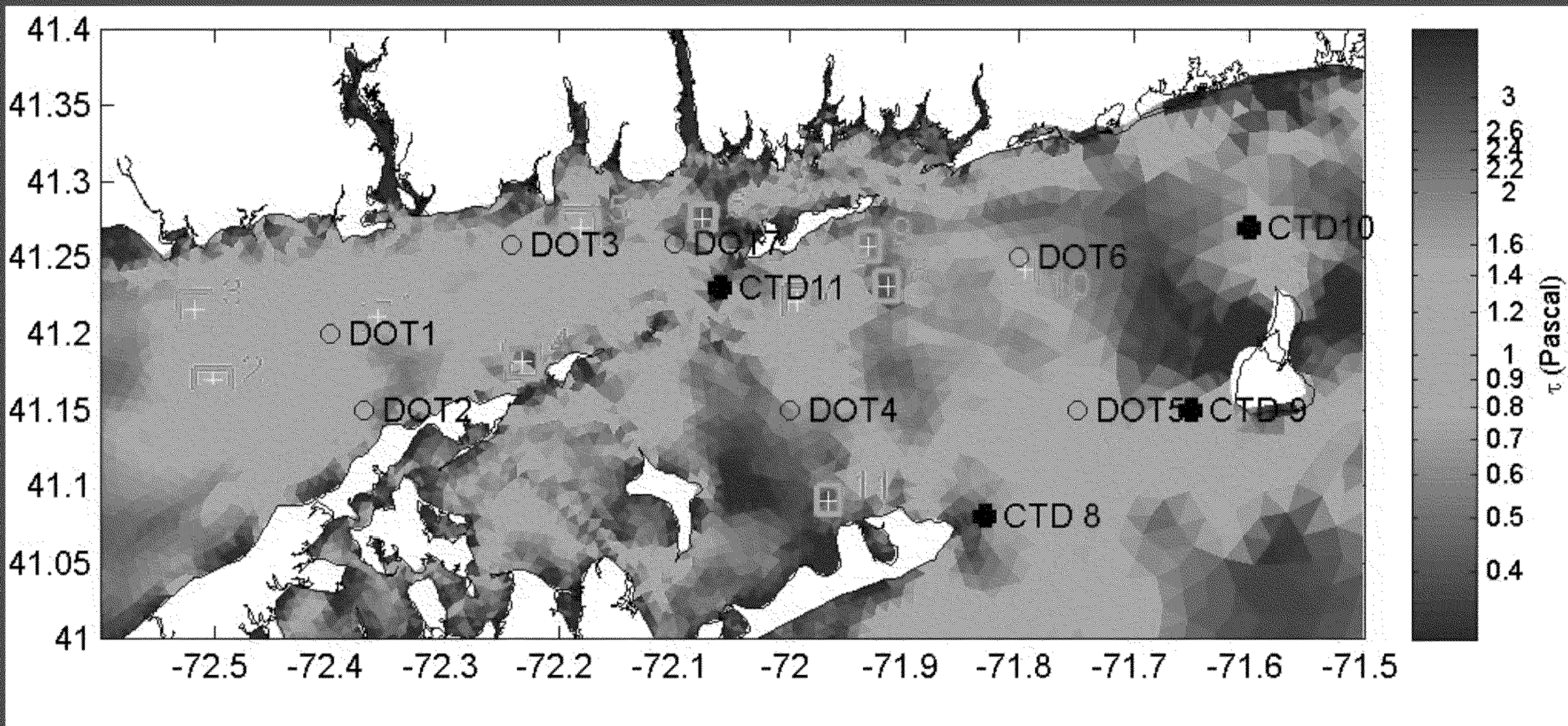
Sites 4 and 10 (Orient Point DS and Block Island Sound DS) show maximum stress below the 0.75 Pa threshold at the center of the site, but have values in excess of 0.75 Pa within the boundary.

Sites 5 and 3 (Niantic Bay and Clinton Harbor) show maximum stresses exceeding 0.75 Pa but less than 1 Pa.

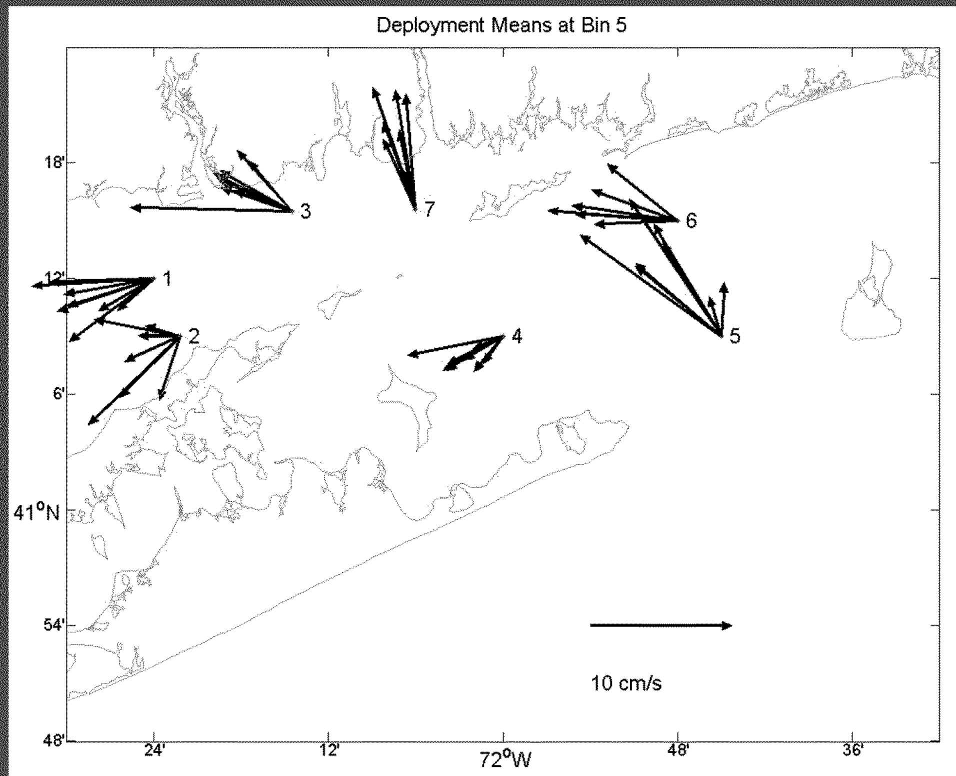


5. Summary

Sites 1, 2, and 7 (Cornfield Shoals, Six Mile Reef, and Fishers Island - west) have high maximum stresses.



5. Summary



Mean Flow is westward at all sites